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REPORT ON POLLUTION OF THE INTERSTATE WATERS OF THE RED RIVER OF THE NORTH (MINNESOTA-NORTH DAKOTA)

T. P. Gallagher

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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The planning and operation of this project was carried out under the supervision of A. D. Sidio, Public Health Engineer.

Assistant project engineers were T. P. Gallagher, Public Health Engineer, and J. E. Hagan, III, Sanitary Engineer.

Mr. Gallagher is the principal author of this report. Mr. Hagan contributed to the hydrology and industrial wastes portions; N. A. Thomas, Aquatic Biologist, prepared the biology section; D. F. Spino, Bacteriologist, contributed to the section on pathogenic bacteria.

All of the above personnel are attached to the Technical Advisory and Investigations Section at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

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INTRODUCTION

At the request of the Governor of the State of Minnesota, the Public Health Service conducted a pollution evaluation survey of the Red River of the North and its major tributaries during the fall and winter of 1964-65. The purpose of the survey was to obtain data on wastes being discharged to this waterway, and to determine the effect of such wastes on the chemical, biological, and bacteriological quality of the river.

The survey was conducted in three parts: the first, in September, 1964, to ascertain conditions when no beet sugar or potato processing wastes were being discharged; the second, in November, 1964, to determine the effect of seasonal industrial wastes discharged to the waters involved; and the third in January, 1965, to observe conditions under ice cover when municipal and some industrial wastes were being discharged.

This report supplements previous reports prepared on this basin by various Federal and State agencies. It could not have been accomplished without the assistance provided by the Departments of Health and Conservation of the State of Minnesota and the Department of Health of the State of North Dakota; by the cities of Fargo and Grand Forks, North Dakota, for providing sites for mobile laboratory accommodations; by the U. S. Army Corps of Engineers for providing additional required information regarding the Red River complex; and by the U. S. Geological Survey for providing flow data. Excellent cooperation was also received from the American Crystal Sugar Company and its representatives in Moorhead, Crookston, and East Grand Forks, Minnesota.

SUMMARY AND CONCLUSIONS

UPPER RED RIVER AND OTTERTAIL RIVER

1. The densities of total coliforms at the mouth of the Ottertail River in September, 1964 exceeded the States' limits for a source of water supply. Four samples out of 11 or 36 percent exceeded 5000 coliform per 100 ml. Two of the 11 samples or 18 percent exceeded 20,000 coliform per 100 ml. The States require that not more than 20 percent exceed the 5000 limit, and not more than 5 percent exceed the 20,000 limit. The Ottertail is used by the cities of Wahpeton and Breckinridge for municipal water supply purposes.

2. Concentrations of total coliforms on the interstate waters of the Bois de Sioux River in September, 1964 were as high as 160,000/100 ml. This pollution is the result of the discharge of untreated sewage at Fairmount, North Dakota.

RED RIVER OF THE NORTH - FARGO TO GRAND FORKS

3. Sewage and industrial waste discharges in the State of Minnesota in this section of the river during this survey amounted to 80,680 population equivalents (P.E.) of which 62,000 P.E. were

the result of industrial waste discharges by the American Crystal Sugar Company at Moorhead, Minnesota. Sewage discharges from North Dakota amounted to 7,300 population equivalents. Of the total wastes contributed to the interstate waters of the Red River of the North in this section, 91 percent originates in the State of Minnesota and 9 percent in the State of North Dakota.

4. In September the discharge of treated sewage from the municipal plants at Fargo and Moorhead caused a reduction in D.O. of 4.5 mg/l in the Red River immediately below the sources of waste. The low mean concentration of 4.4 mg/l with individual values as low as 2.0 mg/l was below the standard of 5 mg/l.

5. The increased loading to the river caused by the discharge of wastes in November from the American Crystal Sugar Company plant at Moorhead reduced D.O. in the Red River to a low mean of 3.5 mg/l. Individual values of D.O. as low as 2.0 mg/l occurred. These low D.O. values are below the standard of 5 mg/l.

6. Under ice cover, the D.O. was reduced to 2.4 mg/l at the Grand Forks water intake by the waste discharges of the Fargo and Moorhead municipal treatment plants. The D.O. was completely depleted at the Grand Forks water intake when the American Crystal Sugar Company plant at Moorhead was discharging clean up wastes under the ice, in violation of the permit granted by the State of Minnesota.

7. Coliform densities in excess of 5000/100 ml occurred in the river in September, 1964 from the Fargo and Moorhead municipal waste sources to Perley, Minnesota, a distance of 43 river miles. Total

coliform means were as high as 865,000/100 ml and fecal coliform had a maximum mean of 233,000/100 ml. These excessive coliform densities are a health hazard to people using this water for purposes such as sport fishing. The gross coliform pollution in this area is the result of unchlorinated municipal sewage effluents at Fargo and Moorhead.

8. The discharge from the American Crystal Sugar Company plant at Moorhead contained densities of 940,000/100 ml for total coliforms and 797,000/100 ml for fecal coliforms in November, 1964. These wastes contributed to the total coliform density of 432,000/100 ml and fecal coliform density of 155,000/100 ml in the river. The municipal plants were also discharging during this period.

9. Total coliform density at the Grand Forks municipal water intake under ice cover amounted to 1,100/100 ml with values as high as 4,900/100 ml. This was a result of unchlorinated municipal waste discharges at Fargo and Moorhead.

10. Salmonella organisms which are pathogenic to man were detected below the sources of waste at Fargo and Moorhead during each phase of this survey and were shown to persist for 73 miles downstream from these sources. Four of the six species of Salmonella classified by the Public Health Service as most commonly infecting man in 1963 were isolated in the Red River of the North below the waste sources at Fargo and Moorhead.

11. The combined wastes from the Fargo and Moorhead municipal treatment plants and the American Crystal Sugar Company plant at

Moorhead reduced pollution-sensitive fish food organisms, produced slimes, and eliminated game fish for a distance of 40 miles in the Red River below the waste outfalls. The excessive increase in suspended algae, which was a result of these waste discharges, was of sufficient density to have caused taste and odor and filter clogging problems at the Grand Forks water plant. Under ice cover, low dissolved oxygen eliminated pollution-sensitive fish food organisms in a 20 mile reach of pool upstream from Grand Forks, 125 miles downstream from the waste sources.

RED LAKE RIVER - CROOKSTON TO GRAND FORKS

12. Discharge from the municipal waste stabilization pond at Crookston, Minnesota in September, 1964 caused bacterial pollution in the Red Lake River. The total coliform density in the Red Lake River at East Grand Forks was 6,570/100 ml. Both Grand Forks and East Grand Forks have water supply intakes in the Red Lake River.

13. The total coliform density of 9,200/100 ml in the Red Lake River at East Grand Forks in November, 1964 was caused by the discharge of wastes from the American Crystal Sugar Company plant at Crookston, Minnesota. The discharge from this plant had a mean total coliform density of 6,360,000/100 ml and a fecal coliform density of 1,400,000/100 ml. The municipal waste stabilization pond at Crookston was not discharging during this period.

14. Wastes from the American Crystal Sugar Company plant at Crookston, Minnesota reduced the population of fish food organisms

and produced slimes that blanketed the stream bed of the entire Red Lake River below the waste outfall and at least two miles of the Red River of the North in the Grand Forks area.

RED RIVER OF THE NORTH - GRAND FORKS TO INTERNATIONAL BOUNDARY

15. Sewage and industrial wastes discharged in the State of Minnesota to this section of the river amounted to 40,000 population equivalents. Sewage and industrial wastes discharged in North Dakota were equal to 105,610 population equivalents. Of the total wastes contributed to the interstate waters of the Red River of the North in this section, 28 percent originated in the State of Minnesota and 72 percent in the State of North Dakota.

16. Excessive bacterial pollution is contributed to the Red River of the North by the Rogers Brothers potato plant and the State Mill sewer in Grand Forks. The discharge from Rogers Brothers contained a total coliform density of 56,300,000/100 ml and a fecal coliform density of 609,000/100 ml. The State Mill sewer discharge contained total and fecal coliform densities of 4,840,000/100 ml and 534,000/100 ml respectively. These bacteria present a health hazard to persons using the waters to which they are discharged.

17. When the municipal waste stabilization ponds at Grand Forks and East Grand Forks were discharging, total coliform density increased in the river from 9,050/100 ml to 56,500/100 ml from above to below the outfalls.

18. During all phases of this study, the total coliform density at the Oslo, Minnesota water intake exceeded the States' standard for a source of water supply. Total coliform densities from 19,000/100 ml to 25,200/100 ml occurred at the Oslo water intake.

19. For conditions of open water, the mean total coliform densities at the International Boundary were less than 3,000/100 ml. Densities under the ice at the International Boundary were 4,800/100 ml for total coliforms and 540/100 ml for fecal coliforms.

20. Excessive concentrations of suspended solids were discharged from the potato plants in Grand Forks. The Pillsbury potato plant wastes had 4,840 mg/l and the Rogers Brothers wastes contained 7,500 mg/l. These suspended solids settle out in the stream and destroy bottom-associated organisms which serve as a food supply for fish. The suspended solids contribution from the potato plants at Grand Forks caused damage to the game fish population in the Red River of the North below the waste outfalls.

21. Salmonella organisms were observed for 10 miles downstream from the municipal and industrial waste discharges at Grand Forks-East Grand Forks in November, 1964. This was a result of wastes discharged in the Grand Forks-East Grand Forks area.

22. Wastes from the Grand Forks and East Grand Forks municipal waste stabilization ponds, the American Crystal Sugar Company plants in East Grand Forks and Crookston, and the Rogers Brothers and Pillsbury potato plants in Grand Forks destroyed fish food organisms and produced biological slimes in a 20 mile reach of the interstate

waters of the Red River of the North downstream from Grand Forks, North Dakota. The changes in the fish food populations and the production of slimes indicate that the water quality of the Red River of the North has been degraded sufficiently to interfere with the aquatic life resources.

* * * * * * * * * * *

Sewage and industrial wastes discharged to the Red River of the North and the Red Lake River from Minnesota cause pollution in the interstate waters of the Red River of the North which endangers the health or welfare of persons in North Dakota and, therefore, is subject to abatement under the provisions of the Federal Water Pollution Control Act. Sewage and industrial wastes discharged to the Red River of the North from North Dakota cause pollution in the interstate waters of the Red River of the North which endangers the health or welfare of persons in Minnesota and, therefore, is subject to abatement under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.).

RECOMMENDATIONS

The recommendations with regard to dissolved oxygen are based on the standard of 5 milligrams per liter of the Missouri Basin Health Council, to which both States subscribe. If the States desire a higher quality than recommended in this report, the objectives of the Federal Government with regard to the effects of interstate pollution on the oxygen resources of the Red River will be accomplished.

Red River of the North - Fargo to Grand Forks

1. Reduction of the waste load from the municipal treatment plants at Fargo and Moorhead will be required whenever flow is less than 80 cfs in the summer and less than 60 cfs in the fall. These flows, on a mean monthly basis, will occur about once in ten years.

2. During the once in 10 year low flow under ice cover, combined waste loads from the municipal treatment plants at Fargo and Moorhead must not exceed 2800 lbs/day of ultimate B.O.D. to maintain 5.0 mg/l as a minimum D.O. in the Red River. Apportioning this load on a sewered population basis, Fargo may discharge 1950 lbs/day of ultimate B.O.D. and Moorhead may discharge 850 lbs/day of ultimate B.O.D.

3. Disinfection of the wastes from the municipal treatment plants at Fargo and Moorhead is required on a year round basis because of the large quantities of coliform bacteria discharged, and because of the isolation of pathogenic Salmonella great distances downstream from the waste sources under adverse environmental conditions.

4. To maintain 5.0 mg/l of D.O. in the river at all times, it will be necessary for the American Crystal Sugar Company plant at Moorhead to discharge waste in accordance with Chart A-5 of the Technical Appendix. During the once in 10 year low spring flows, a total of about 550,000 pounds of B.O.D. from the American Crystal Sugar Company at Moorhead may be discharged.

5. Because nutrients discharged in the sewage and industrial wastes from Fargo and Moorhead cause excessive biological growth downstream, the maximum practical reduction of the nitrogen and phosphorus in these wastes should be accomplished as soon as reasonably possible.

Red Lake River - Crookston to East Grand Forks

6. Reduction of the wastes from the American Crystal Sugar Company plant at Crookston, Minnesota will be required at river discharges less than 330 cfs to maintain 5.0 mg/l of D.O. in the Red Lake River. This flow can be expected on the average about three times in eight years. Experimental reduction in waste loads should be made to control the severe deleterious effect on the bottom-associated

and fish food organisms in this reach.

7. The excessive total and fecal coliform densities in the American Crystal Sugar Company wastes at Crookston should be reduced to ensure that the densities in the Red Lake River at East Grand Forks will not exceed the States' standard for a source of water supply.

Red River of the North - Grand Forks to the International Boundary

8. All sanitary sewage discharged to the Red River of the North at Grand Forks-East Grand Forks should be connected to the municipal collection systems and treated in the municipal waste stabilization ponds, or separate adequate treatment provided in accordance with present plans.

9. Wastes from the potato plants presently discharging to the Red River at Grand Forks should be collected and sent to the municipal system following in-plant treatment.

10. If the recommendation for treatment of the potato plant wastes in the municipal system is accomplished, the present discharge of 9,000 lbs/day of B.O.D. during the fall campaign from the American Crystal Sugar Company plant at East Grand Forks may be continued. However, if slime growths develop and accelerate the rate of deoxygenation and if the discharge creates a significant benthal demand, reduction of wastes during the fall may be required. No discharge can be permitted under ice cover.

BACKGROUND

In 1931, '32, and '33 an investigation of the Red River of the North was made by the Minnesota and North Dakota State Boards of Health. Again in February, 1938, the two State Health Departments made a joint investigation of the Red River. It was concluded from the results obtained that " . . . it will be necessary to provide treatment for the sewage and industrial wastes from all of the municipalities from Breckinridge to Grand Forks and East Grand Forks inclusive, and for all the major industrial wastes which are discharged separately into the section of the river under consideration."

In 1944, the interstate ramifications of the pollution led to the establishment of a formal Tri-State Waters Commission and an informal Interstate Sanitation Committee involving the States of North Dakota, Minnesota, and South Dakota in a cooperative effort to solve the water problems of the basin. In 1949, the Committee set up standards recommended for use by the respective regulatory agencies for sewage and waste treatment facilities discharging to the Red River of the North and tributaries. These standards are stated as follows:

"It is recommended that industry and municipalities treat their wastes to the point where the average daily composite 20°C., B.O.D. is 25 ppm, suspended solids 30 ppm, with no peaks running over 50 ppm 20°C., 5-day B.O.D. and 60 ppm suspended solids. Chlorination shall not be used as means of obtaining the B.O.D. reductions although it may be required for other purposes. Certain types of industrial wastes, such as those resulting from the processing of agricultural products, may have to be considered on an entirely different basis.

"It is further recommended that these standards be considered as general only, and that they be subject to modification to meet specific pollutional programs as they develop." Subsequently, these standards were adopted by the respective State regulatory agencies.

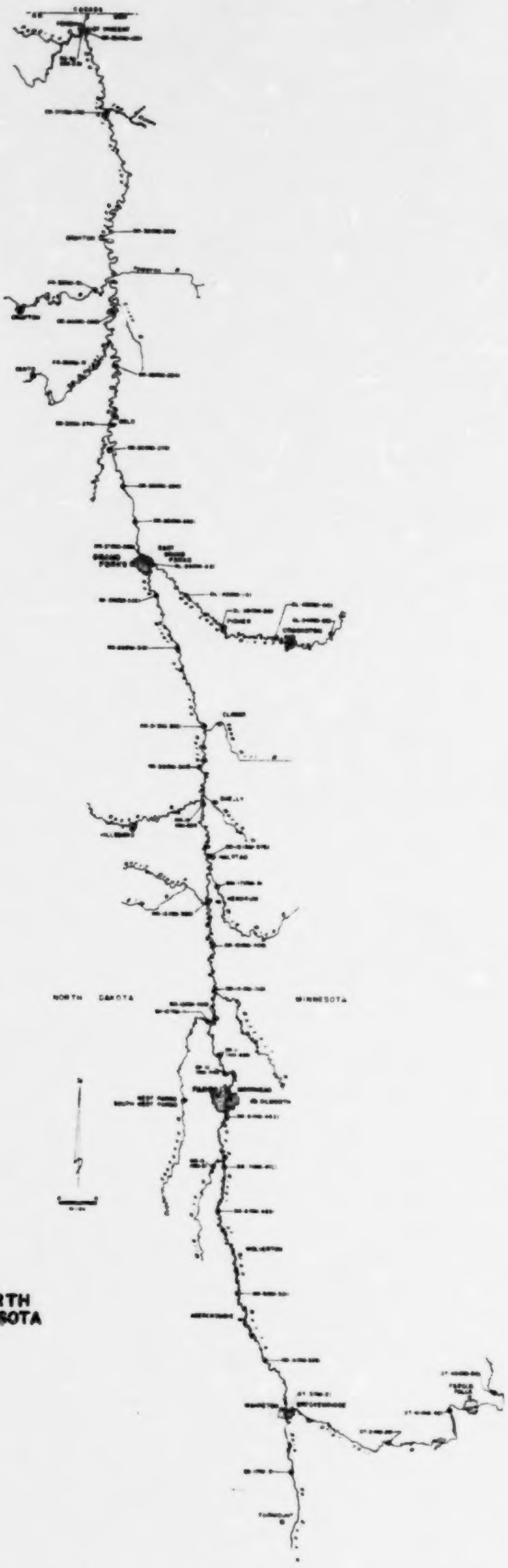
In November, 1951, a cooperative State-Federal report on water pollution in the Missouri-Souris development area and including the Red River of the North basin was issued. This report was prepared by the Public Health Service in close collaboration with the water pollution control agencies of the States in the basin, including North Dakota and Minnesota. The water pollution control agencies reviewed the report and approved its contents as it applies to their respective States. In its consideration of the Red River of the North, the report states that:

"The criteria (of the Interstate Sanitation Committee) essentially establish the principle of secondary treatment for all organic wastes discharging to the Red River or to tributaries where they have an appreciable effect on the Red River."

BASIN DESCRIPTION AND STUDY AREA

The Red River of the North is formed by the confluence of the Ottertail and Bois de Sioux rivers at the twin cities of Wahpeton, North Dakota, and Breckinridge, Minnesota, and flows north for 549 river miles to Lake Winnepeg, Canada: 394 river miles are in the United States. The river forms the boundary between the States of Minnesota and North Dakota. It slopes very gently toward the north, falling about 200 feet in 400 miles within the United States through both impounded and unimpounded stretches. Tributary river systems of major importance are the Ottertail River, the Sheyenne River, the Red Lake River, and the Pembina River. The Red River Valley was, in prehistoric times, the bed of an inland glacial lake which varied in width from 15 to 70 miles. The plain of the Red River Valley is composed of a very rich black earth, which is exceptionally well suited for agricultural purposes, particularly the cultivation of wheat, sugar beets, and potatoes. The metropolitan areas of Fargo-Moorhead and Grand Forks-East Grand Forks serve the principally agricultural economy as rail and trucking centers.

The study area may be divided into four parts. The first was the Ottertail River from above Fergus Falls to Breckinridge, Minnesota, and the upper Red River from Wahpeton-Breckinridge to Fargo-Moorhead, having a total of 146 river miles. The second consisted of the Red River between Fargo-Moorhead and Grand Forks-East Grand Forks, with 164 river miles. The third was the Red Lake River from above Crookston to its confluence with the Red River at Grand Forks-East Grand Forks, 66 river miles. The fourth reach extended on the Red River from Grand Forks-East Grand Forks to the International Boundary; this amounted to 143 river miles. A total of 519 river miles was involved in the three phases of this study. The entire study area is shown in Chart 1.


NORTH DAKOTA
MINNESOTA

RED RIVER OF THE NORTH
NORTH DAKOTA – MINNESOTA

STUDY AREA

CHART I

METHOD OF STUDY

The three phases of this study involved a total of 43 river sampling stations on the Red River and nine of its tributaries. The main stem of the Red River of the North had 27 sampling locations from Wahpeton-Breckinridge to the International Boundary. Five stations were located on the Red Lake River from above Crookston, Minnesota to the confluence with the Red River at East Grand Forks, Minnesota. The Ottertail River had four sampling stations from above Fergus Falls to its mouth in Breckinridge, Minnesota. Seven other tributaries had sampling stations located near their confluence with the Red River to monitor the effect of their water quality upon the interstate waters of the Red River. These tributaries included the Bois de Sioux River, the two Wild Rice rivers in North Dakota and Minnesota, the Sheyenne River, the Forest River, the Park River, and the Pembina River. In addition, the wastes from six industrial users, including the three sugar refining plants of the American Crystal Sugar Company at Moorhead, East Grand Forks and Crookston, Minnesota, were intensively sampled during periods of plant operation. A description of all sampling stations is contained in Table 1.

Table 1

Red River of the North

North Dakota - Minnesota

Sampling Station Location Guide

Station Number	River Mileage	Description
BD-1	549-9	Bois de Sioux River highway bridge near Tyler, N.D.
OT-2	549-27	Ottertail River highway bridge, 8 miles east of Doran, Minnesota
OT-3	549-1	Ottertail River highway bridge, 4th Street N. and Andrews Avenue, Breckinridge, Minnesota
	549	U.S.G.S. gage, Wahpeton, North Dakota
RR-4	536	Red River of the North highway bridge near Brushvale, Minnesota
RR-5	501	Red River of the North highway bridge near Enloe, North Dakota
RR-6	483	Red River of the North highway bridge near Comstock, Minnesota
RR-7	472	Red River of the North highway bridge near Wild Rice, North Dakota
WD-8	470-2	Wild Rice River highway bridge near Wild Rice, North Dakota
RR-9	462	Red River of the North, Interstate 94 highway bridge, Fargo, North Dakota
RR-10	441	Red River of the North highway bridge, N.E. of Fargo Airport, Fargo, North Dakota
RR-11	436	Red River of the North bank sample on private property, 4 miles N. of Moorhead, Minnesota
RR-12	426	Red River of the North bank sample on private property, near Kragnes, Minnesota
SH-13	428-1	Sheyenne River highway bridge, Cass County Rd. 81, 8 miles N. of Fargo, N.D.

Table 1 (Cont.)

Red River of the North

North Dakota - Minnesota

Sampling Station Location Guide

Station Number	River Mileage	Description
RR-14	416	Red River of the North highway bridge near Georgetown, Minnesota
RR-15	403	Red River of the North highway bridge near Perley, Minnesota
RR-16	386	Red River of the North highway bridge near Hendrum, Minnesota
WM-17	380-3	Wild Rice River near Hendrum, Minnesota
RR-18	375	Red River of the North highway bridge near Halstad, Minnesota Also U.S.G.S. gage
RR-19	357	Red River of the North highway bridge near Shelly, Minnesota
RR-20	347	Red River of the North highway bridge near Nielsville, Minnesota
RR-21	335	Red River of the North highway bridge near Climax, Minnesota
RR-22	319	Red River of the North highway bridge near Bygland, Minnesota
RR-23	305	Red River of the North bank sample on private property, 4 miles S. of East Grand Forks, Minnesota
RL-24	298-66	Red Lake River highway bridge, 5 miles E. of Crookston, Minn.
	298-51	U.S.G.S. gage, Crookston, Minn.
RL-25	298-28	Red Lake River highway bridge at Fisher, Minnesota
RL-26	298-0	Red Lake River Highway 220 bridge at East Grand Forks, Minnesota

Table 1 (Cont.)

Red River of the North

North Dakota - Minnesota

Sampling Station Location Guide

Station Number	River Mileage	Description
RR-27	298	Red River of the North, Demers Ave. bridge, Grand Forks, N. D. - East Grand Forks, Minn.
	296	U.S.G.S. gage, Grand Forks, N. D.
RR-28	292	Red River of the North bank sample on private property, 4 miles N. of East Grand Forks, Minn.
RR-29	286	Red River of the North bank sample on private property, near Northland, Minn.
RR-30	279	Red River of the North bank sample on private property, 2 miles S. of Oslo, Minn. on North Dakota side of the river.
RR-31	274	Red River of the North highway bridge at Oslo, Minnesota Also U.S.G.S. gage, Oslo, Minn.
RR-32	254	Red River of the North bank sample on private property near Big Woods, Minn.
FR-33	243-7	Forest River, Highway 44 bridge, N. D.
RR-34	236	Red River of the North highway bridge east of Grafton, N. D.
PR-35	222-5	Park River, Highway 44 bridge, N. D.
RR-36	208	Red River of the North highway bridge at Drayton, N.D. Also U.S.G.S. gage, Drayton, N. D.
RR-37	176	Red River of the North bank sample on private property near Joliette, N. D.
PE-38	158-D	Pembina River highway bridge at Pembina, N. D.
RR-39	158	Red River of the North highway bridge at Pembina, N.D.
	155	International Border
	154	Canadian Gaging Station, Emerson, Manitoba

Table 1 (Cont.)

Red River of the North
North Dakota - Minnesota
Sampling Station Location Guide

Station Number	River Mileage	Description
OT-40	549-67	Ottertail River highway bridge, 4 miles E. of Fergus Falls, Minn.
OT-41	549-49	Ottertail River highway bridge, 2.5 miles W. of Fergus Falls, Minn.
RL-42	298-14	Red Lake River highway bridge near Mallory, Minn.
RL-43	298-49	Red Lake River bank sample as municipal lagoons, Crookston, Minn.
SM-44		American Crystal Sugar Co., Moorhead, Minn. plant outfall
SC-45		American Crystal Sugar Co., Crookston, Minn. plant outfall
SE-46		American Crystal Sugar Co., East Grand Forks, Minn. plant outfall
RP-47		Rogers Brothers Potato plant, Grand Forks, N. D. plant outfall
PP-48		Pillsbury Potato plant, Grand Forks, N. D. plant outfall
FP-49		Frito-Lay Potato plant, Grand Forks, N. D. plant outfall
SM-50		North Dakota State Mill, Grand Forks, N. D. sewer outfall

RIVER DISCHARGE

During each phase of the study, flows were obtained at each of the sampling stations with the assistance of the U. S. Geological Survey. These values are listed in Table 2. These data show that there were no extreme variations in river discharge at any point during the individual sampling periods. During the September, 1964 survey, the discharge in the river and tributary system was below the average that normally occurs. In October-November, and in January, discharge was about the average monthly flow at Fargo. At Crookston and Grand Forks, during this period, discharge was about twice the average monthly flow due to an abnormally high release of water from the flood control dam on the Red Lake River. These flood control dams, located on the Ottertail and Red Lake rivers, are maintained by the Corps of Engineers. During low water periods, releases are made from these reservoirs to meet downstream water requirements including water supply and waste disposal. These releases are coordinated.

The Red River of the North exhibits a large increase in flow from its headwaters to the International Boundary. The Ottertail River normally supplies 90 percent of the flow to the Red River at its inception at Wahpeton-Breckinridge. Downstream at Fargo-Moorhead,

Table 2

River Discharges

Red River of the North & Tributaries

Station	River Mile	River Discharge (cfs) Sept.	Nov.	Jan.
Red River of the North				
RR- 9	462	70	234	189
RR-10	441	75	230	194
RR-11	436	76	229	190
RR-12	426	148	292	
RR-14	416	182	318	265
RR-15	403	185	319	262
RR-16	386	187	316	260
RR-18	375	218	380	292
RR-19	357	225	378	295
RR-20	347	232	384	300
RR-21	335	298	401	312
RR-22	319	325	401	315
RR-23	305	333	401	315
RR-27	298	607	1512	955
RR-28	292	625	1515	952
RR-29	286	648	1525	949
RR-30	279	662	1525	946
RR-31	274	698	1545	940
RR-32	254	711	1561	933
RR-34	236	739	1591	928
RR-36	208	766	1611	922
RR-37	176	800	1562	907
RR-39	158	868	1524	898

Table 2 (Cont.)

River Discharges

Red River of the North & Tributaries

Station	River Mile	River Discharge (cfs)		
		Sept.	Nov.	Jan.
Red Lake River				
RL-24	298-66	247	1063	
RL-43	298-49		1065	
RL-25	298-28	254	1093	
RL-42	298-14		1106	
RL-26	298- 0	276	1115	647
Tributaries				
OT-2	549-20	69		
OT-3	549-2	77		
BD-1	549-9	6		
WD-8	468-2	1		
SH-13	428-1	67	64	69
WM-17	380-3	29	67	33
FR-33	243-7	6	11	
PR-35	222-5	8	7	
PE-38	158-0.5	113	50	5
Upper Red River				
RR-4	536	85		
RR-5	501	83		
RR-6	483	73		
RR-7	472	71		

The Sheyenne River adds from 20 to 100 percent of the flow in the Red River depending on the season of the year. The Red Lake River effectively doubles the discharge of the Red River at Grand Forks - East Grand Forks. The discharge of the Red River normally is ten times greater at the International Boundary than at Fargo. This is due primarily to the inflow from the major tributaries, notably the Sheyenne and Red Lake rivers.

WATER USAGE

Water usage in the Red River study area is principally for domestic and industrial water supply and waste disposal. However, there is some agricultural use, such as irrigation. Fishing, especially ice fishing, is quite popular and constitutes the major recreational use. There is limited pleasure boating in the impounded areas.

DOMESTIC WATER SUPPLY

Within the study area, the rivers are used as sources of domestic water supply by approximately 161,000 people, a great majority of the area's population. Fifty-six thousand of these are in Minnesota and 105,000 are in North Dakota. Fargo, North Dakota, obtains its water supply from the Red River of the North. The city of Grand Forks has two intakes; one on the Red River of the North above the city, and the other on the Red Lake River. Comparison of water quality in both rivers dictates the choice of intake to be used in supplying the domestic needs for the city. Other major users of the rivers for municipal water supply include Fergus Falls, Breckinridge, Crookston, and East Grand Forks, Minnesota, and Wahpeton, Drayton and Pembina, North Dakota. Domestic water users are listed in Table 3.

Table 3

Domestic Water Supply

Red River Study Area

Community	Population Served	Source of Supply
Fergus Falls, Minn.	14,000	Ottertail River
Wahpeton, North Dakota	6,000	Red River & Ottertail R.
Breckinridge, Minn.	4,500	Ottertail River
Fargo, North Dakota	49,000	Red River of the North
Grand Forks, N. D.	48,140	Red River & Red Lake R.
East Grand Forks, Minn.	7,300	Red Lake River
Crookston, Minn.	9,500	Red Lake River
Oslo, Minn.	370	Red River of the North
Drayton, N. D.	950	Red River of the North
Pembina, N. D.	625	Pembina River

INDUSTRIAL WATER SUPPLY

Industrial water use in the study area is estimated at about fifteen million gallons per day (MGD). Principal users are the American Crystal Sugar Company's beet processing plants located at Moorhead, Crookston, and East Grand Forks, Minnesota; several potato processing plants located principally in Grand Forks, North Dakota; and a meat packing and rendering plant in Fergus Falls. With the exception of the meat packing and rendering plant, these operations are seasonal, occurring during the fall and winter months. Steam electric generating plants, located in Fargo, Grand Forks and Fergus Falls, use about 40 MGD of river water for cooling purposes.

RECREATION

Although the Red River at present is not intensively developed for recreational purposes, there is some potential for an increase in this use. Impoundments in the Red River at Fargo-Moorhead result in a pool of more than twenty miles in length which is suitable for small pleasure boating. There is also a pool in the Red River at Grand Forks which extends for about thirty-nine river miles. Limited pleasure boating was observed in this pool during this study.

Fishing may be observed frequently in all areas, in open water and under the ice. The most intensive fishing location observed during this study was in the tailrace of the last dam downstream in Fargo-Moorhead. This dam is only a few feet upstream from the outfall of the Moorhead sewage treatment plant. During winter, ice fishing shanties could be seen everywhere, but were especially numerous at the mouth of the Red Lake River at East Grand Forks. Sport fishing represents the major recreational use at the present time.

AGRICULTURE

Agriculture represents the pillar upon which the economy of the area is built. Without a highly productive agricultural output, the economic well being of the region will suffer. Since this region has poorly distributed rainfall characteristics over the year, water conservation is a necessity and some irrigation of crops is carried on. Because the ground waters of the area are inadequate in quantity and of poor quality, the conservation must be accomplished on the surface water resources. If the quality of surface water is poor, it cannot be used for irrigation purposes. Cattlemen who depend on the rivers for stock water would be forced to either import water or to cut down the size of their herds. The drop in productivity due to inadequate surface water quality would adversely affect existing industry and hinder the development of new industry.

WASTE DISCHARGES

The Red River and its tributaries are used extensively for the disposal of wastes, both municipal and industrial, which cause serious water quality degradation in certain reaches.

DOMESTIC WASTES

The strength of sewage commonly is measured in terms of three constituents: oxygen demand, bacterial content, and suspended solids. These may be expressed in population equivalents, the units of which are the average contribution of these constituents made by an individual in a day. The domestic waste facilities which discharge at various times to the Red River of the North and its tributaries within the study area and the contribution of each in population equivalents are listed in Table 4.

Most communities in the basin use waste stabilization ponds and discharge intermittently to the receiving streams. From those communities who employ other methods of treatment or none at all, there was a continuous daily discharge of domestic wastes to the Red River of the North and its tributaries with a total oxygen demand of 37,530 population equivalents (P.E.). The corresponding values for

Table 4
Domestic Waste Discharges
Red River of the North

Municipality	Receiving Waterway	Population Served	Type of Treatment	Population Equivalents Discharged		
				Oxygen Demand	Bacterial	Suspended Solids
Minnesota						
Fergus Falls	Ottertail River	29000*	Secondary & Cl.	14700	2900	2500
Wolverton	Red River of the North	180	Primary	120	90	90
Moorhead	Red River of the North	48700**	Secondary & Cl.	13000	2100	7000
Halstad	Red River of the North	580	None	580	580	580
Shelly	Marsh River	280	W.S.P.***	30	5	10
Climax	Sand Hill River	280	None	280	280	280
Crookston	Red Lake River	7690	W.S.P.	770	80	250
East Grand Forks	Red River of the North	6300	W.S.P.	630	60	180
Total from Minnesota		93010		30110	5695	10890
North Dakota						
Fairmount	Bois de Sioux River	500	None	500	500	500
Wahpeton	Red River of the North	4700	W.S.P.	470	50	150
Abercrombie	Red River of the North	200	Primary	140	120	120
Fargo	Red River of the North	47000	Secondary	7300	4700	6900
West Fargo	Sheyenne River	120	Secondary	12	12	12
Southwest Fargo	Sheyenne River	3000	W.S.P.	300	30	90
Grand Forks	Red River of the North	30000	W.S.P.	3000	300	900
Grafton	Park River	5640	W.S.P.	560	50	150
Drayton	Red River of the North	910	None****	910	910	910
Pembina	Pembina River	485	W.S.P.	50	5	15
Total from North Dakota		92555		13242	6677	9747

* 16600 Industrial P.E.

** 28000 Industrial P.E. estimated from plant records.

*** Waste stabilization ponds. Overall removal of B.O.D. is greater than 90% on a concentration basis.

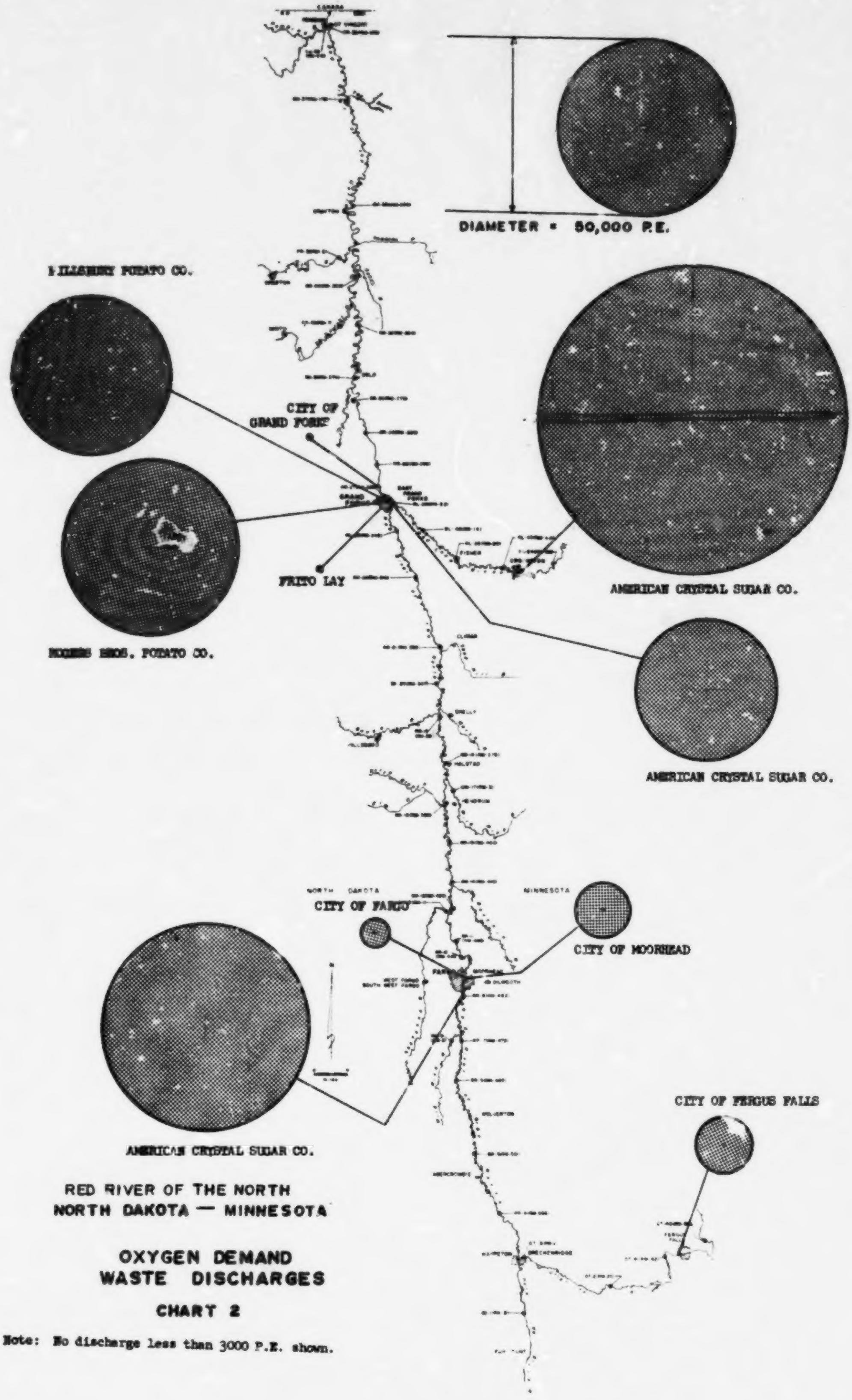
**** Stabilization pond treatment begun in 1965.

bacterial (B.P.E.) and suspended solids (S.S.P.E.) were 9650 and 19000 population equivalents respectively. Most of this daily contribution was from the metropolitan and industrial center of Fargo-Moorhead. The raw sewage P.E. from this complex was 67,640. Both communities provide biological secondary treatment of their wastes and the combined population equivalents of the effluents from the two treatment plants are: oxygen demand P.E. 20,300; B.P.E. 6,800; and S.S.P.E. 13,900. The Moorhead plant, however, contributes about two-thirds of the oxygen demand waste effluent.

Of those communities that provide no treatment, Halstad, Minnesota, with a sewered population of 580, has plans in the design stage for construction of a secondary treatment plant, while Drayton, North Dakota, with a population of 950, has a waste stabilization pond under construction which will be ready for operation in 1965. Fairmount, North Dakota, and Climax, Minnesota, with a total population of 780, continue to discharge their wastes with no treatment.

Most of the remaining sewage discharges in the study area that may affect the quality of interstate waters occur intermittently due to the seasonal lowering of stabilization pond levels. These ponds provide about six months' storage to the wastes and they are discharged during the spring and fall seasons.

Charts 2 and 3 illustrate the relative oxygen demand P.E. and the B.P.E. of wastes discharged to the receiving streams.

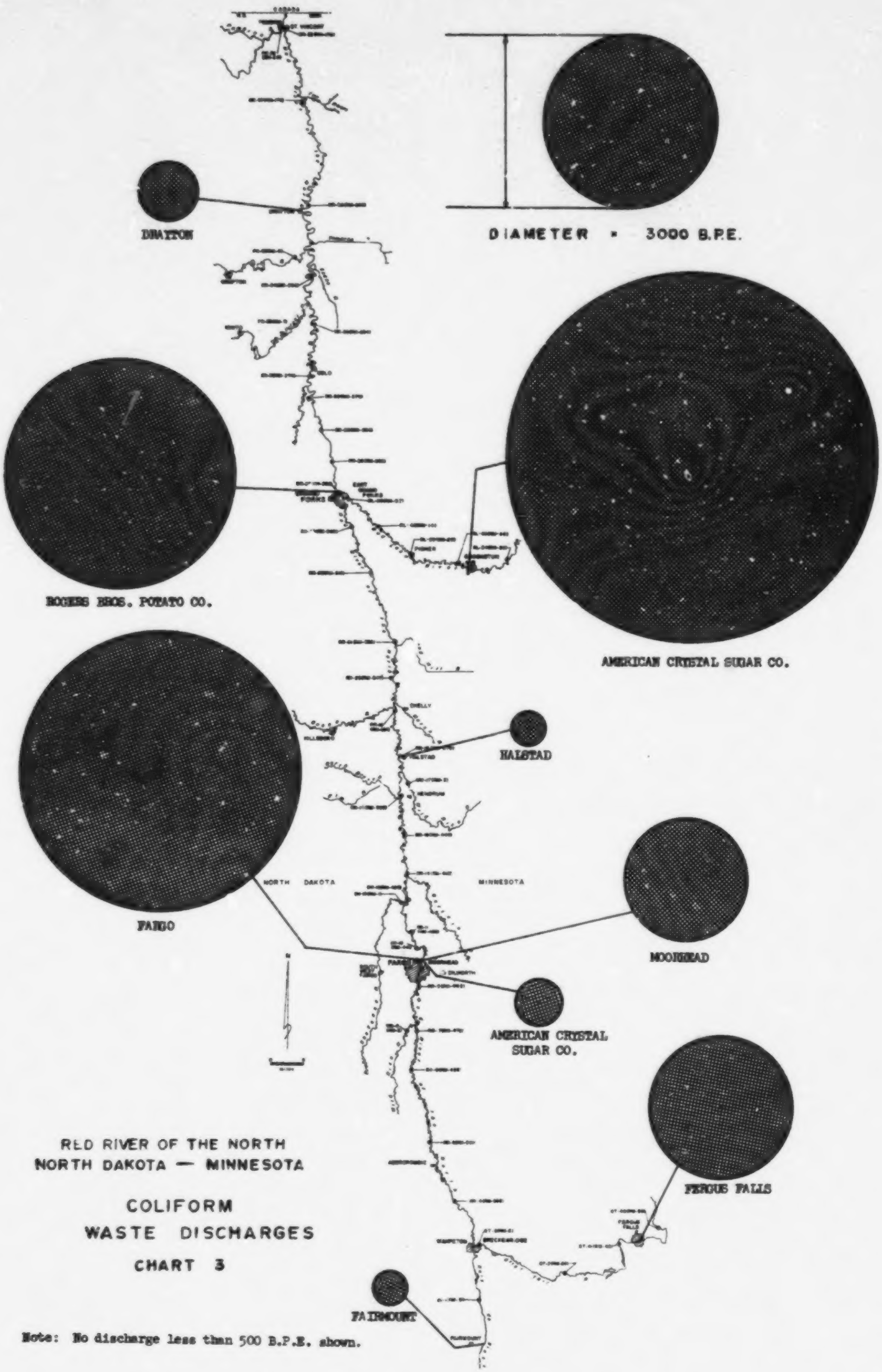

DIAMETER = 50,000 P.E.
PILLSBURY POTATO CO.
CITY OF GRAND FORKS
FRITO LAY
AMERICAN CRYSTAL SUGAR CO.
RODGERS BROS. POTATO CO.
AMERICAN CRYSTAL SUGAR CO.
NORTH DAKOTA
MINNESOTA
CITY OF FARGO
CITY OF MOORHEAD
AMERICAN CRYSTAL SUGAR CO.
CITY OF FERGUS FALLS

RED RIVER OF THE NORTH
NORTH DAKOTA — MINNESOTA

OXYGEN DEMAND
WASTE DISCHARGES

CHART 2

Note: No discharge less than 3000 P.E. shown.


CANADA
DRAYTON
DIAMETER = 3000 B.P.E.
ROGERS BROS. POTATO CO.
AMERICAN CRYSTAL SUGAR CO.
HALSTAD
NORTH DAKOTA
MINNESOTA
FARGO
MOORHEAD
AMERICAN CRYSTAL SUGAR CO.
FERGUS FALLS
FAIRMOUNT

RED RIVER OF THE NORTH
NORTH DAKOTA — MINNESOTA

COLIFORM
WASTE DISCHARGES
CHART 3

Note: No discharge less than 500 B.P.E. shown.

INDUSTRIAL WASTES

Industrial wastes, within the study area, are primarily those from the processing of agricultural products, especially potatoes and sugar beets. Chart 2 shows the relative oxygen demand P.E. of industrial wastes discharged to the receiving streams.

The American Crystal Sugar Company currently operates sugar beet processing plants at Moorhead, Crookston, and East Grand Forks, Minnesota, and has a fourth plant under construction at Drayton, North Dakota. The discharge of wastes from these plants is regulated by the State of Minnesota depending on stream flow. These plants begin operation in the fall, usually soon after Labor Day, and operate on a daily 24-hour schedule until the supply of beets is exhausted. A normal campaign runs about 150 days. However, the waste discharge schedule does not correspond to the campaign schedule. From the beginning of the campaign until the ice cover on the receiving streams near 100 percent, wastes are discharged from the plants to lagoons and to the river with little detention in the lagoons. When ice cover is complete, the lagoon outlets are closed and the wastes are stored until spring for release during periods of high river flow. Table 5 indicates the population equivalents of the three sugar plant discharges during the survey period of October-November, 1964. Totals of 191,000 oxygen demand P.E., 7,135 B.P.E., and 38,000 S.S.P.E. were discharged by the three plants.

Three potato processing plants in Grand Forks, North Dakota, discharge directly to the Red River of the North. Operations of the

Table 5
Industrial Waste Discharges*
Red River of the North

Plant	State	Receiving Waterway	Treatment	Population Equivalents Discharged		
				B.O.D.	Bacteria	Suspended Solids
American Crystal Sugar Co. Moorhead	Minn.	Red River of the North	Lagoons	62,100	765	18,350
American Crystal Sugar Co. Crookston	Minn.	Red Lake River	Lagoons	89,300	6,350	9,000
American Crystal Sugar Co. East Grand Forks	Minn.	Red River of the North	Lagoons	39,400	-	10,700
Rogers Brothers Potato Co. Grand Forks	N. D.	Red River of the North	Primary	52,700	3,910	105,500
Pillsbury Potato Co. Grand Forks	N. D.	Red River of the North	None**	46,000	-	68,500
Frito Lay Potato Co. Grand Forks	N. D.	Red River of the North	Primary	3,000***	-	-
				101,700		
Total Industrial Wastes				292,500	11,045	212,000

* These figures obtained during Oct.-Nov. 1964 PHS Survey.
** Primary provided - not in use at time of sampling.
*** Estimated.

101,700
30,000
130,000 Pop = 200 P/A
600

Rogers Brothers and Pillsbury plants are seasonal during the fall and winter months, depending upon the supply of potatoes. Table 5 indicates the population equivalents of the potato plant wastes during the October-November, 1964 phase of the survey. Totals of 101,700 oxygen-demanding P.E. and 174,000 S.S.P.E. were discharged by the three plants. The Frito-Lay Company was not in operation due to an equipment breakdown, and the estimate of 3,000 P.E. was obtained from other sources. The wastes being discharged from these plants have extremely high concentrations of oxygen demand and suspended solids. The excessive suspended solids (174,000 P.E.) discharged from these potato plants settle out in the stream and destroy bottom-associated organisms which serve as a food supply for fish. The Rogers Brothers plant, where a steam type peeling process is used, contributed significant quantities of bacteria amounting to 3910 B.P.E. In the future, these potato plant wastes, after effective primary treatment has been provided at the plant, will be collected and treated in the Grand Forks municipal system.

WASTE TOTALS

During this study there was a daily discharge of wastes, both municipal and industrial, to the Red River of the North and its tributaries of 330,230 oxygen-demanding P.E.; 20,965 B.P.E.; and 231,000 S.S.P.E. Two hundred nineteen thousand population equivalents of oxygen-demanding wastes or 66 percent of the total were discharged in Minnesota and the remainder in North Dakota. Seventy-nine percent or 183,000 S.S.P.E. were discharged in North Dakota. Each State contributed about an equal amount of B.P.E.

For municipal wastes alone, Minnesota contributed 28,560 P.E., or 76 percent of the daily load on an oxygen demand basis. For industrial wastes, Minnesota contributed 191,000 oxygen demand P.E. or 65 percent of the total. For suspended solids, North Dakota contributed 174,000 S.S.P.E., or 82 percent of the total.

EFFECTS OF POLLUTION ON WATER QUALITY

BIOCHEMICAL OXYGEN DEMAND AND DISSOLVED OXYGEN

Sewage and many industrial wastes contain organic matter that decomposes and exerts an oxygen demand in the receiving waters. In the process of decomposition, oxygen derived from the atmosphere and dissolved in the water is reduced below its normal level of concentration to satisfy this biochemically degrading organic material. High concentrations of oxygen-demanding material will cause an excessive reduction of the dissolved oxygen resources which, in turn, will result in a reduction of desirable aquatic life and fish population. If the wastes are strong enough to cause a complete depletion of the dissolved oxygen, offensive odors will result.

Neither the State of Minnesota nor the State of North Dakota has established a dissolved oxygen standard for the waters of the Red River of the North or its tributaries. Both States, however, support the use of the standards of the Missouri Basin Health Council which recommend a minimum D.O. of 5.0 mg/l. If the States desire a higher quality than that recommended in this report, the objectives of the Federal Government with regard to the effects of interstate pollution on the oxygen resources in the Red River will be accomplished.

Ottertail River and Upper Red River

This section of the study area does not have an intensively developed water use since it consists mainly of many small agricultural communities. The waste loads discharged are relatively small and the average biochemical oxygen demand (B.O.D.) in this reach was 3 mg/l. There is one major source of continuous waste at Fergus Falls, Minnesota. Fergus Falls discharges effluent from a secondary sewage treatment plant that includes wastes from a packing and rendering plant, to the Ottertail River above the Orwell flood regulation dam. Whatever oxygen-demanding material remains after treatment becomes diluted in the impoundment. In addition, the time of passage is increased appreciably, allowing for satisfaction of any B.O.D. in the immediate area.

The observed dissolved oxygen (D.O.) values are shown in Chart 4. In this section, no average D.O. value was less than 7.5 mg/l. Since the results of this phase of the survey in this section revealed no interstate pollution problems and since waste loads remain relatively constant, it was not considered necessary to sample during the latter two study periods.

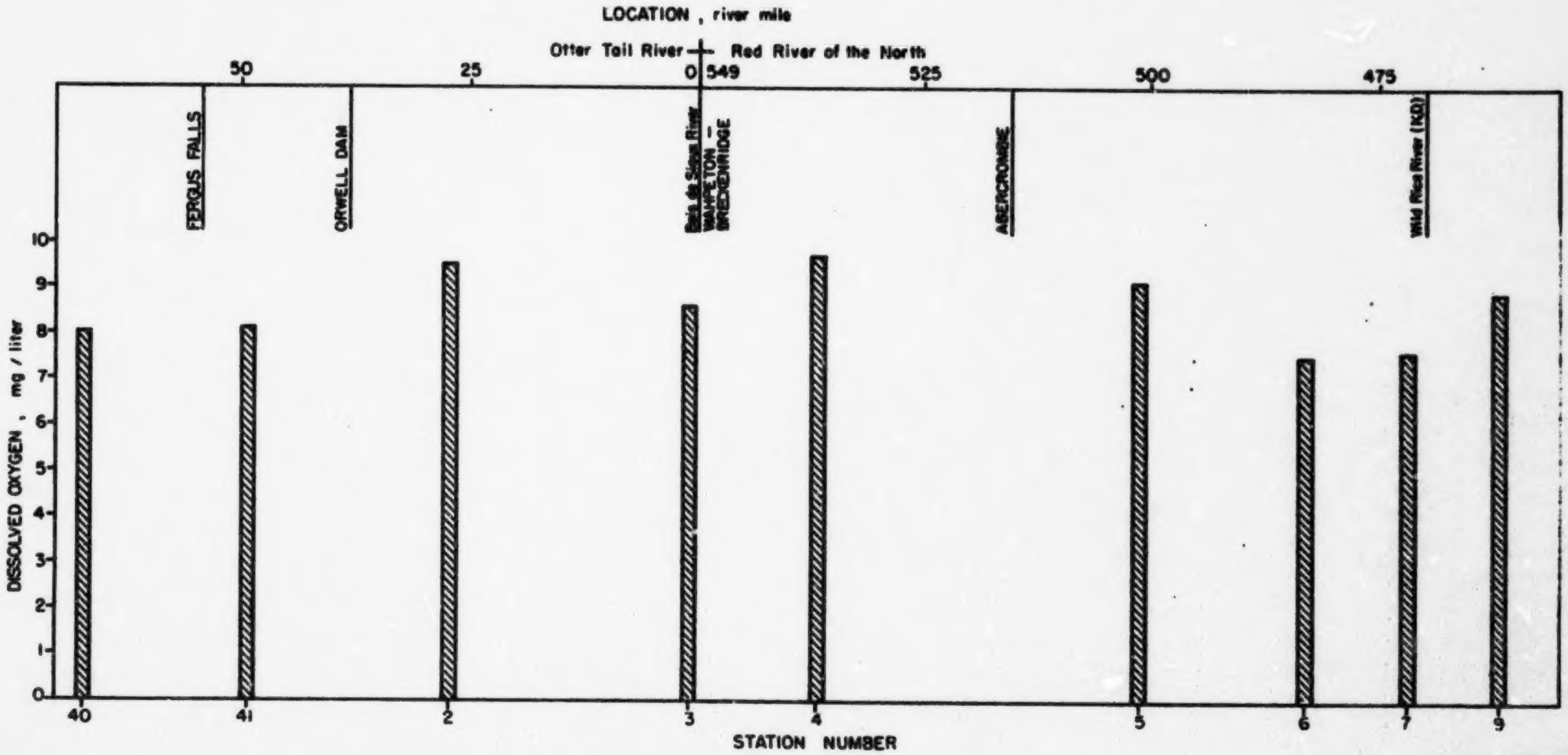


Chart 4

RED RIVER OF THE NORTH
North Dakota — Minnesota
Otter Tail and Upper Red River
DISSOLVED OXYGEN

Red River of the North - Fargo to Grand Forks

The mean values obtained in this stretch are summarized in Table 6 and are illustrated in Chart 5.

During September the American Crystal Sugar Company's beet processing plant at Moorhead was not in operation and was not discharging wastes to the river. The condition of the river during September reflected the effects of the discharges from the two secondary sewage treatment plants at Fargo and Moorhead and from any contribution of waste materials by the tributaries. From immediately above Fargo-Moorhead to immediately below the two sources of municipal wastes, there was an increase of 15,000 population equivalents (P.E.) of B.O.D. The exertion of the oxygen demand of these wastes was immediately reflected in the D.O. concentrations in the stream. From 8.9 mg/1 above the sewage plant discharges the concentration dropped to 4.4 mg/1 below. Individual values of D.O. at this point were as low as 2.0 mg/1. The D.O. recovered through reaeration until it reached a value greater than saturation at a point 45 miles downstream.

During November, the beet sugar plant at Moorhead was operating on a 24-hour, 7-day week schedule, and was discharging waste with an average B.O.D. of 62,000 P.E. The two municipal plants continued to discharge. The increased organic loading imposed a marked reduction in D.O. The D.O. dropped from 10.8 mg/1 above Fargo-Moorhead to 3.5 mg/1 at a point 12 miles downstream. Individual values of D.O. at this point were as low as 2.0 mg/1. The river then recovered until it reached its pre-waste level of D.O. at Halstad, Minnesota, a distance of 73 miles downstream from the sources of waste.

Table 6

Dissolved Oxygen
Red River of the North
Fargo to Grand Forks
Sept.-Nov. 1964

Station	River Mile	Dissolved Oxygen Sept. mg/1	Dissolved Oxygen Nov. mg/1
RR- 9	462	8.9	10.8
RR-10	441	4.4	5.8
RR-11	436	5.9	3.5
RR-12	426	8.1	4.8
RR-14	416	8.3	6.5
RR-15	403	10.0	8.0
RR-16	386	12.4	10.0
RR-18	375	14.0	11.1
RR-19	357	11.7	12.2
RR-20	347	9.9	12.9
RR-21	335	9.0	13.6
RR-22	319	8.1	14.8
RR-23	305	6.9	16.2

Table 6 (Cont.)
Dissolved Oxygen
Red River of the North
Fargo to Grand Forks
January, 1965

Station	River Mile	Dissolved Oxygen 1 mg/l	Dissolved Oxygen 2 mg/l
RR- 9	462	12.7	12.7
RR-10	441	10.6	11.3
RR-11	436	9.3	9.0
RR-14	416	4.4	6.1
RR-15	403		5.9
RR-16	386	4.1	5.2
RR-18	375	4.8	4.9
RR-19	357	2.5	3.4
RR-20	347	2.7	3.9
RR-21	335	3.3	5.0
RR-22	319	1.1	4.2
RR-23	305		3.0
Grand Forks water intake	300		2.4

1 - Mean of values resulting from ACS-Moorhead clean-up operation.

2 - Mean of values not affected by ACS-Moorhead clean-up operation.

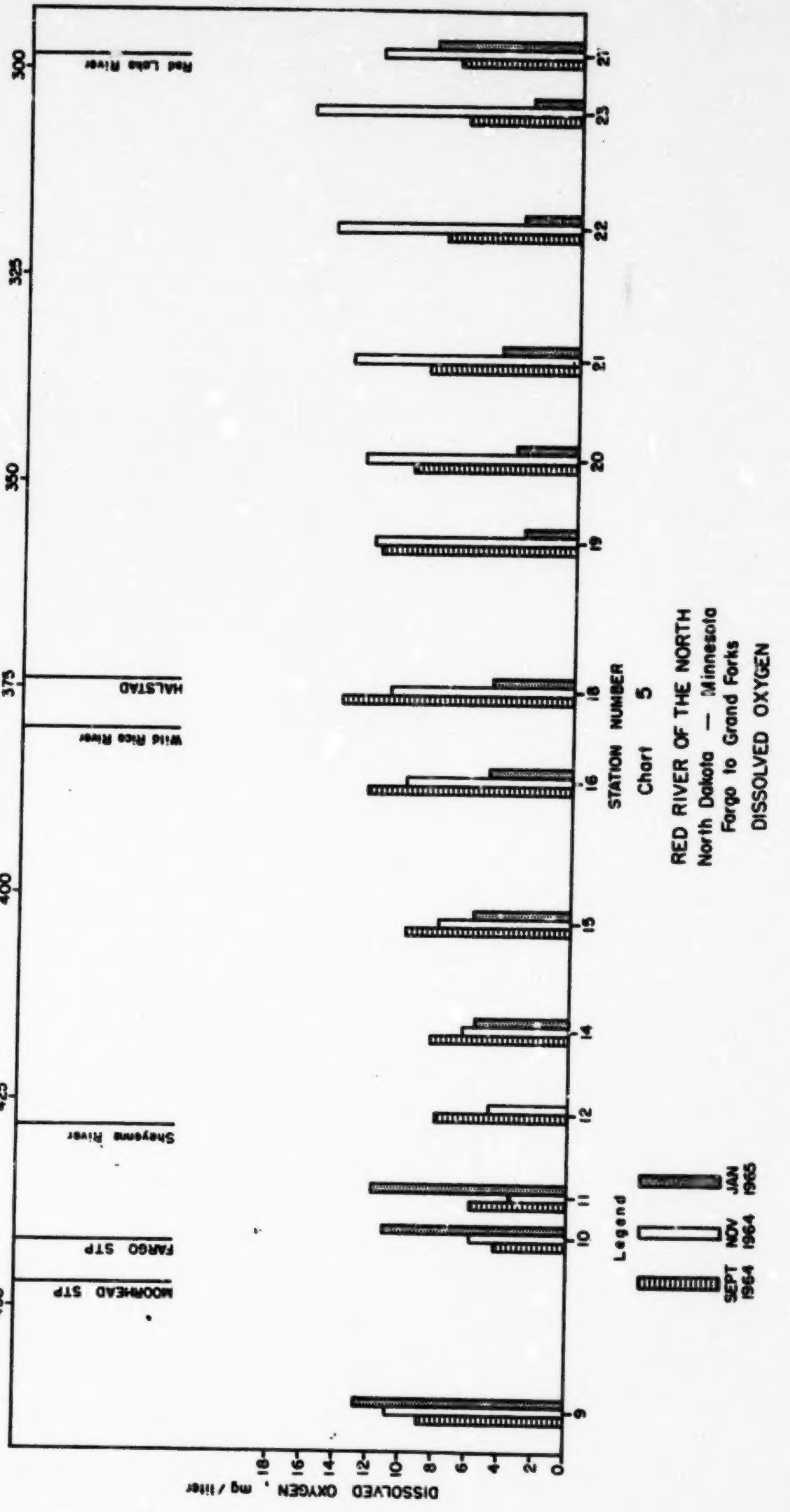


Chart 5

RED RIVER OF THE NORTH
North Dakota — Minnesota
Fargo to Grand Forks
DISSOLVED OXYGEN

In September and November, the D.O. continued to increase downstream from the points of minimum D.O. and supersaturated concentrations occurred. The highest mean values were 14 mg/l at Halstad in September and 16.2 mg/l in the impoundment above Grand Forks in November. This production of oxygen was caused by algae growths in the river. Downstream of R.M. 347 in September, the production of oxygen by algae was no longer apparent. The D.O. in this reach dropped from 9.9 mg/l at R.M. 347 to 6.9 mg/l at R.M. 305. Algae cannot be considered beneficial to the stream since a serious additional demand on the oxygen resources may be created by their respiration and by their decomposition when the supply of nutrients for their growth has been depleted. The excessive algal growth in this reach of river was caused by the discharge of wastes from domestic and industrial sources at Fargo and Moorhead.

The survey conducted under ice cover in January, 1965, revealed a totally different picture of the oxygen balance than that observed in September and November. The beet sugar plant at Moorhead was discharging clean-up wastes for four days at the beginning of the survey, in violation of the permit for discharge issued by the State of Minnesota. When the beet sugar plant was not discharging, the increase in B.O.D. was 24,000 P.E. During the four days when the beet sugar plant was discharging, the increase in B.O.D. was 72,000 P.E. The decrease in D.O. was more pronounced under the increased loading from the sugar plant waste. At Grand Forks, the D.O. approached depletion (2.4 mg/l) due to the waste discharges of the Fargo and Moorhead municipal treatment plants. The D.O. dropped to zero at the Grand Forks water intake under the conditions of increased demand added by the discharge of the sugar plant.

Red Lake River - Crookston to Grand Forks

Table 7 summarizes the data observed in this stretch.

During September, the only source of pollution to this stretch was the discharge from the lagoon at Crookston. The increase in B.O.D. from this discharge amounted to 3,000 P.E., and there was a slight drop in the D.O. from 9.2 mg/1 to 8.8 mg/1. Chart 6 represents the D.O. profile in the river.

In November, the American Crystal Sugar Company plant at Crookston was discharging wastes to the river. The increase in B.O.D. below the discharge was 118,000 P.E. The release from the Red Lake flood control dam during this period was substantially above the expected flow. Oxygen resources from the increased flow (1065 cfs) and from atmospheric reaeration prevented a sharp drop in D.O., such as occurred below Fargo-Moorhead (234 cfs). The D.O. was reduced only 1.5 mg/1 in this stretch before starting to recover. The B.O.D. observed in the Red Lake River immediately before its confluence with the Red River was 92,000 P.E. No significant numbers of algae, and no meaningful production of oxygen, were observed in this stretch.

During January, 1965, there was no discharge from the sugar plant and a monitoring station in East Grand Forks showed the D.O. to be 11.6 mg/1 after prolonged ice cover. This indicated little demand on the oxygen resources.

Table 7

Dissolved Oxygen

Red Lake River

Crookston to Grand Forks

Station	River Mile	Dissolved Oxygen Sept. mg/1	Nov. mg/1	Jan. mg/1
RL-24	298-66	9.2	12.0	
43	298-46		11.2	
25	298-28	8.8	10.7	
42	298-14		11.4	
26	298-0	8.5	10.6	11.6

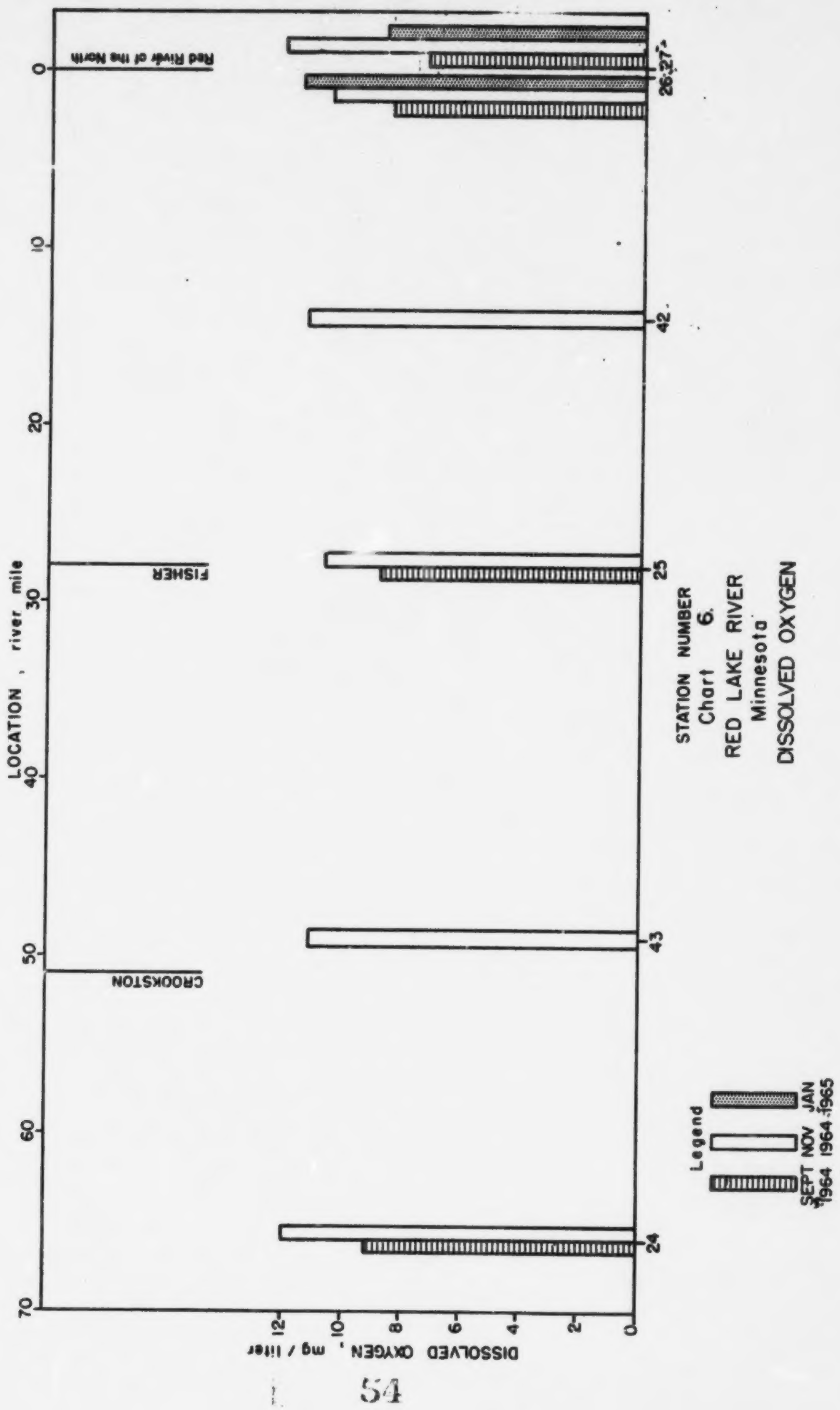


Chart 6.
RED LAKE RIVER
Minnesota
DISSOLVED OXYGEN

Red River of the North - Grand Forks to International Boundary

The results obtained in this stretch are summarized in Table 8 and illustrated in Chart 7. During the September phase of the survey, the sources of pollution to this stretch were the residual pollution from Fargo-Moorhead and the discharge from the municipal waste stabilization ponds at Grand Forks and East Grand Forks. The D.O. in the river at R.M. 298 downstream of the confluence with the Red Lake River was 7.4 mg/l. The B.O.D. between R.M. 298 and R.M. 292 increased 25,000 population equivalents, due to the discharge from the two municipal waste stabilization ponds. There was no decrease of the D.O. at these loadings and the minimum discharges plus the increased dilution prevented damage during September. Although B.O.D. values were extremely high in the Park and Forest rivers, tributary to the Red in this stretch, the very low flows do not permit this waste to measurably affect the Red River.

In November, industries were discharging wastes in the Grand Forks-East Grand Forks area. The wastes included those from the American Crystal Sugar Company in East Grand Forks and from the Rogers Bros., Pillsbury, and Frito Lay potato plants in Grand Forks. The municipal waste stabilization ponds were also discharging during this period. Residual oxygen demand from the Red Lake River and from the Red River above Grand Forks contributed to the total oxygen demand below Grand Forks. The combined industries in Grand Forks-East Grand Forks contributed 125,000 P.E. to the river. Because of the unusually high stream flows and atmospheric reaeration replenishing the oxygen supply, the effect of the waste discharges on the D.O. gradient was

120,000

Table 8

Dissolved Oxygen

Red River of the North
Grand Forks to International Boundary

Station	River Mile	Dissolved Oxygen Sept. mg/l	Dissolved Oxygen Nov. mg/l	Dissolved Oxygen Jan. mg/l
RR-27	298	7.4	12.2	8.8
28	292	8.2	11.6	
29	286	8.2	11.1	
30	279	8.5	11.2	10.8
31	274	8.5	11.2	10.8
32	254	9.0	11.4	
34	236	8.8	11.6	10.4
36	208	8.9	11.8	10.2
37	176	9.4	11.7	
39	158	9.0	11.7	11.9

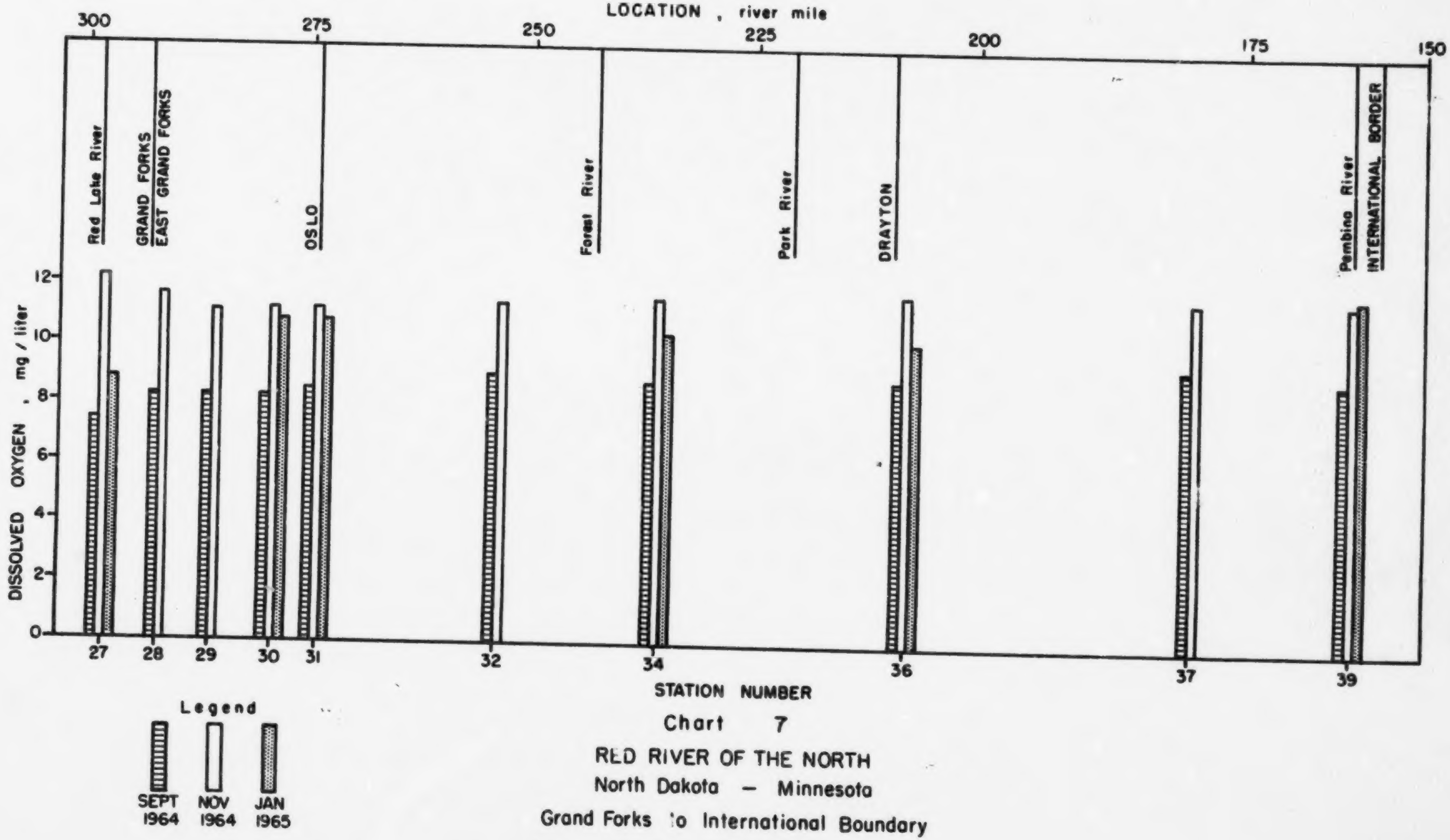


Chart 7

RED RIVER OF THE NORTH

North Dakota – Minnesota

Grand Forks to International Boundary

DISSOLVED OXYGEN

minor. At the International Boundary during this period the B.O.D. was 3.5 mg/l and the D.O. was 11.7 mg/l.

In January, potato wastes were being discharged intermittently in the Grand Forks area. The D.O. at R.M. 298 was 8.8 mg/l, which reflected the very low D.O. in the Red River above Grand Forks. The D.O. was increased to 10.8 mg/l by aeration over the dam at Grand Forks and remained fairly constant to the International Border. When the river crossed the Border under ice cover, the D.O. was 11.9 mg/l. The B.O.D. during January averaged 1.5 mg/l, which is about the level normally found in unpolluted waters. Under present conditions, there appears to be no oxygen depletion problem under ice cover in the reach from Grand Forks-East Grand Forks to the International Boundary.

BACTERIA

Waste effluents contain enormous numbers of bacteria, among which there are usually pathogenic organisms that can cause gastrointestinal diseases such as typhoid fever and diarrhea. These pathogenic bacteria can cause illness in persons who swallow water containing them. As the densities of pathogenic bacteria are reduced or eliminated through waste treatment and disinfection, the hazards of contracting disease are proportionately reduced or eliminated. Methods for the detection of these pathogenes have, up to now, been too complicated for practical use in field determination. However, a more refined method of detection which has recently become available now makes possible the isolation of Salmonella genus, one of the most common pathogenes infecting man, in a relatively easy and convenient manner. This analysis was performed at certain locations during each phase of this survey.

Waste effluents contain bacteria of the coliform group which typically occur in excreta or feces and can readily be detected. These bacteria, usually harmless in themselves, are always present in river water which receives some form of waste and have, therefore, been used as an indication of the probable presence of pathogenic organisms. The possibility of pathogenic organisms being present in the absence of coliform organisms is extremely remote. The coliform group has been used by numerous state and interstate water pollution control agencies as a basis for water quality objectives for various water uses. These standards are based on total coliform densities and objections to their use have been based primarily on the fact that certain coliform species may be derived from sources other than excreta. Recently, a method for specific detection of fecal coliform bacteria has been developed. The U. S. Public Health Service drinking water standards to which both States subscribe say in a discussion of the sanitary significance of fecal coliform that: "Fecal coliform organisms may be considered indicators of recent fecal pollution. No satisfactory method is currently available for differentiating fecal coliform organisms of human and animal origin. Therefore, it is necessary to consider all fecal coliform organisms as indicative of dangerous contamination." Both total and fecal coliform densities were determined on all samples. The results of both determinations are expressed in most probable numbers or MPN, per 100 milliliters (ml) of water. The mean values used in this report are geometric averages.

Both States involved have adopted the Public Health Service recommended standard for quality of a raw water to be used as a source of water supply. This standard states that the total coliform density in no more than 20 percent of the samples examined in any month may be greater than 5000/100 ml, and no more than 5 percent of the samples examined in any month may be greater than 20,000/100 ml. In areas which are not used as a source of water supply, the States subscribe to a standard of 5000/100 ml mean coliform density.

COLIFORM BACTERIA

Ottertail River and Upper Red River

The mean values for this stretch are summarized in Table 9 and illustrated in Chart 8. The only large contributor of bacteriological pollution to the Ottertail is the discharge from the sewage treatment plant at Fergus Falls, Minnesota. This effluent causes an increase in mean total coliform density in the river from 210/100 ml to 16,200/100 ml, and in fecal coliform density from 24/100 ml to 4,760/100 ml. The Ottertail is impounded below Fergus Falls by the Orwell flood control dam, where dilution and dieoff reduce the bacterial densities appreciably. The highest value observed below Fergus Falls and above Orwell Dam was 160,000/100 ml for total coliforms and 54,000/100 ml for fecal coliforms. At the mouth of the Ottertail River the average density of total coliforms was 4,820/100 ml and 610/100 ml for fecal coliforms. Densities were as high as 54,000/100 ml for total coliforms and 7,900/100 ml for fecal coliforms at this point. It is apparent that the waters which are used by the cities of Wahpeton and Breckinridge for municipal supply should be limited as a source of water supply because of the health hazard involved, unless steps are taken to reduce the coliform densities.

High values of both total and fecal coliforms occurred on the Bois de Sioux River with concentrations of total coliforms as high as 160,000/100 ml. This pollution is the result of the discharge of untreated sewage from Fairmount, North Dakota.

In the interstate waters of Red River, total densities were

Table 9

Coliform Bacteria
Ottertail River and Upper Red River
September 1964

Station	River Mile	Coliform Densities (MPN/100 ml)	
		Total	Fecal
Ottertail River			
OT-40	549-59	210	24
OT-41	549-42	16,200	4,760
OT-2	549-20	1,200	177
OT-3	549-2	4,820	610
Upper Red River			
RR-4	536	4,170	300
RR-5	501	3,920	400
RR-6	483	1,160	43
RR-7	472	4,700	131
Tributaries			
BD-1	549-9	2,800	540
WD-8	468-2	2,960	295

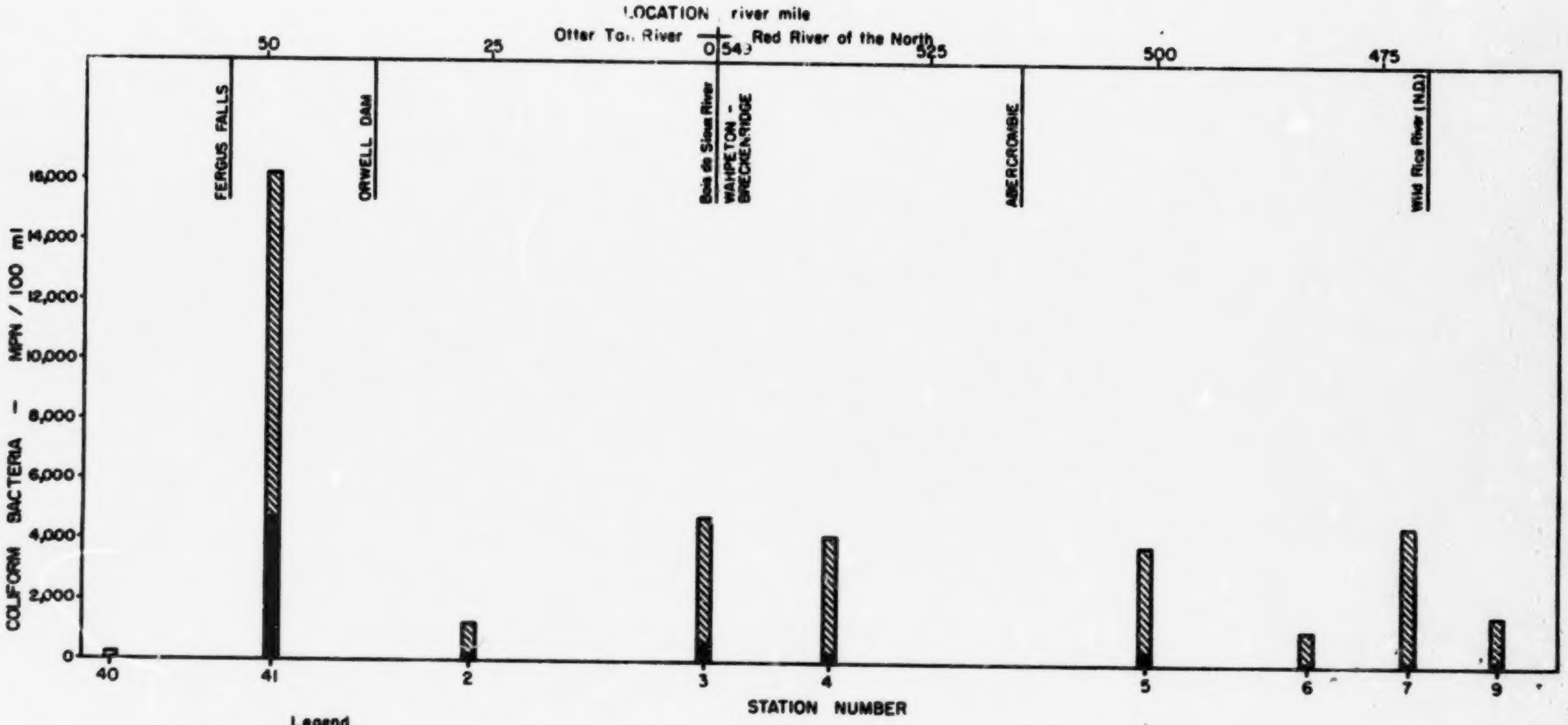


Chart 8

RED RIVER OF THE NORTH
North Dakota — Minnesota
Otter Tail and Upper Red River
COLIFORM BACTERIA

within the 5000/100 ml limit for coliforms for the reach between Wahpeton-Breckinridge and Fargo-Moorhead. The lowering of the waste stabilization pond at Wahpeton, North Dakota, did not appreciably affect the coliform densities in the river. In the impoundment at Fargo and close to the water supply intake for Fargo, the total coliform count was 1730/100 ml with a maximum density of 4600/100 ml and the fecal count was 236/100 ml with maximum value of 1400/100 ml. Since waste loads do not vary appreciably in this reach, sampling was limited to the September phase of the study.

Red River of the North - Fargo to Grand Forks

The mean values for this stretch are summarized in Table 10 and illustrated in Chart 9. The major sources of bacteriological contamination in this stretch of river are the unchlorinated effluents from the two secondary sewage treatment plants at Fargo and Moorhead and the discharge from the beet sugar processing plant at Moorhead when it is in operation.

During September, with the sugar plant not operating, the combined discharges from the municipal treatment plants produced a mean coliform density in the river below Fargo-Moorhead at R.M. 441 of 865,000/100 ml total coliforms, with a minimum value of 79,000/100 ml and a mean density of 233,000/100 ml of fecal coliforms with a minimum of 33,000/100 ml. Values as high as 2,800,000/100 ml of total and 790,000/100 ml of fecal coliforms were obtained at this sampling point. The coliform densities were reduced quite rapidly downstream to Hendrum, R. M. 386, where they were approximately at the same level as that

Table 10

Coliform Bacteria
Red River of the North
Fargo to Grand Forks

Station	River Mile	Coliform Densities (MPN/100 ml)					
		Sept.		Nov.		Jan.	
		Total	Fecal	Total	Fecal	Total	Fecal
RR-9	462	1,730	236	314	49	530	450
RR-10	441	865,000	233,000	432,000	155,000	162,000	61,000
RR-11	436	250,000	64,500	249,000	85,600	83,500	34,000
RR-12	426	47,600	2,850	68,000	16,800		
RR-14	416	16,800	1,510	27,100	8,160	18,600	9,170
RR-15	403	4,590	500	20,300	5,310	19,100	10,800
RR-16	386	990	126	6,630	1,610	7,800	5,160
RR-18	375	1,970	117	4,180	722	6,140	2,950
RR-19	357	2,200	26	2,650	780	9,900	3,930
RR-20	347	1,260	23	1,130	250	3,520	1,970
RR-21	335	13,300	82	1,410	247	4,760	2,600
RR-22	319	710	43	125	20	1,600	820
RR-23	305	1,160	55	48	20	1,280	590
G. F. Water Intake	300					1,100	340
SH-13	428-1	68,000	1,530	1,410	203	650	218
WM-17	380-3	12,450	4,550	3,670	1,820	10,800 *	3,780

* Large numbers of ice fishing shanties were observed on the river at this sampling location.

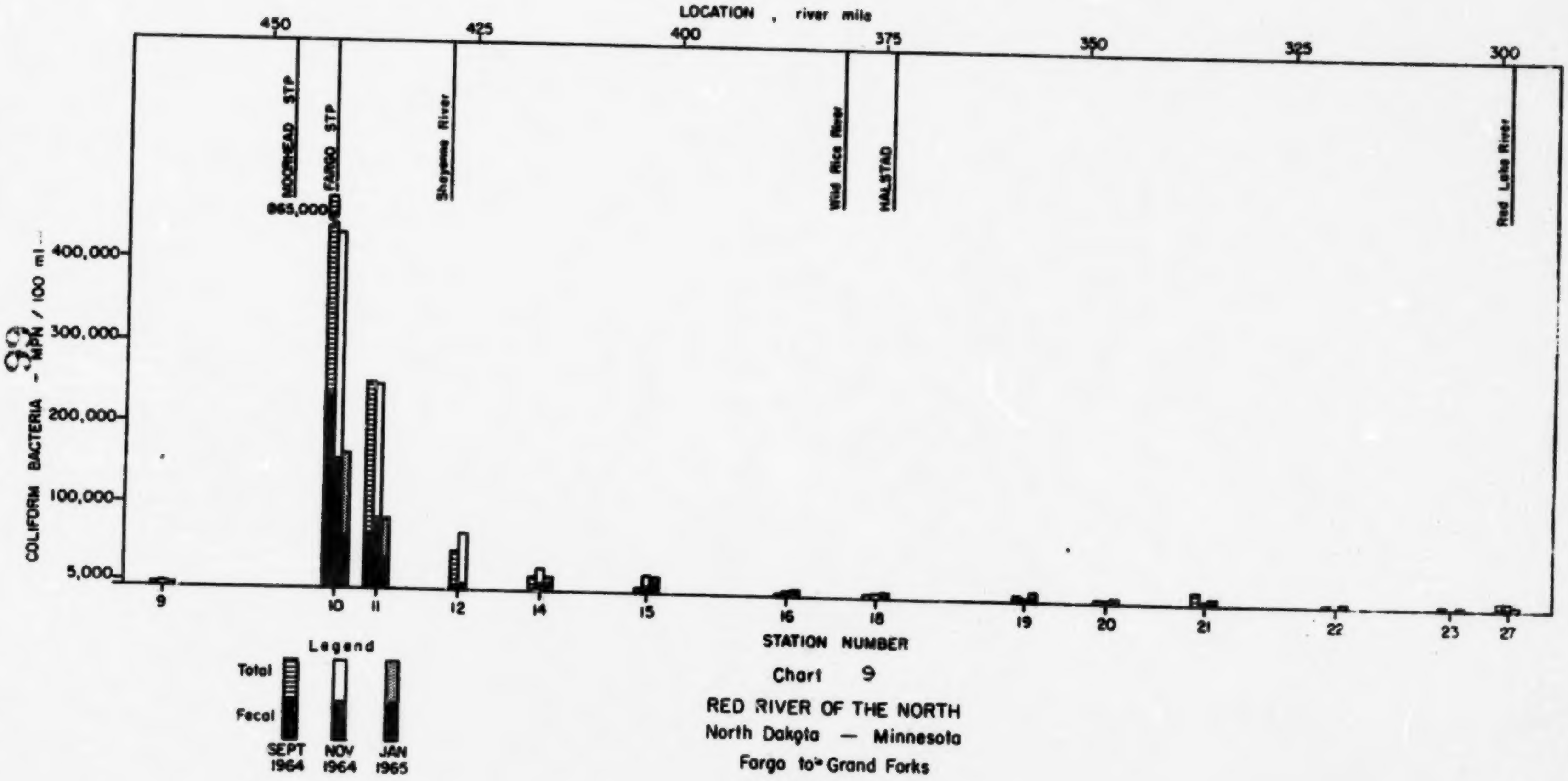


Chart 9

RED RIVER OF THE NORTH
North Dakota — Minnesota
Fargo to Grand Forks
COLIFORM BACTERIA

upstream of sewage discharges. The Sheyenne River contributed a large quantity of coliform bacteria (68,000/100 ml) to the Red River but the fecal coliform density was relatively low (1,530/100 ml) indicating that most of the pollution was probably not from human or animal origin. The Wild Rice River in Minnesota contributed a comparatively high coliform density, which was reflected in the total coliforms in the Red River but not in the fecal coliforms. Concentrations remained low throughout the remainder of the stretch except for a mean of 13,300/100 ml in total coliforms at R.M. 335 near Climax, Minnesota. The mean at this station was high because of several extreme values produced by a localized rainstorm and, since the fecal coliform density did not increase appreciably, may be considered to be due to land runoff from the storm.

During November, 1964, with stream flow about three times that in September, the mean coliform density increased from 314/100 ml to 432,000/100 ml from above Fargo-Moorhead to below the sources of waste. The corresponding values for fecal coliform densities were from 49/100 ml to 155,000/100 ml. Although the densities in November were less than those in September, with the higher stream flow in November the total numbers of coliforms were greater in November than in September, and total numbers of fecal coliforms were about twice as great. The only source of bacteria during November other than sewage from Moorhead and Fargo was the beet sugar plant waste at Moorhead. The effluent from this plant had total coliform densities of 940,000/100 ml and fecal coliform densities of 797,000/100 ml. The sugar plant discharge, therefore, contributed large densities of bacterial pollution. The bacteria decreased slowly in November and the total coliform densities remained above the standard for more than 100 river miles downstream from the waste sources. The densities were higher than the level observed above the waste discharges for nearly 130 miles downstream. The Sheyenne and Wild Rice rivers had comparatively low total and fecal coliform densities during this period. The total and fecal coliform densities in the impoundment immediately above Grand Forks were negligible.

In January, the same waste discharge conditions as in September prevailed except for a short period when the sugar beet plant was releasing wastes from a clean-up operation. The total coliform density in the river increased from 530/100 ml to 162,000/100 ml. Both total and fecal coliforms persisted longer in January, with its colder temperatures, than in November. The coliform densities in January at Halstad, Minnesota, were measurably higher and fecal coliforms were four times greater than in November. Data in Table 10 illustrate this observation. Coliform densities in January, under ice cover, were higher in the impoundment immediately above Grand Forks than they were during any other time of sampling. At the Grand Forks water intake, the mean total coliform density was 1100/100 ml with values as high as 4900/100 ml.

Red Lake River - Crookston to Grand Forks

The mean bacterial densities observed in this stretch are summarized in Table 11 and illustrated in Chart 10. During most of the year there was no discharge of waste to this stretch of the Red Lake River. In September, sewage was discharged from the municipal waste stabilization pond in Crookston to lower the pond level in preparation

Table 11

Coliform Bacteria
Red Lake River
Crookston to Grand Forks

Station	River Mile	Coliform Densities (MPN/100 ml)					
		Sept.		Nov.		Jan.	
		Total	Fecal	Total	Fecal	Total	Fecal
RL-24	298-66	918	35	3,040	670		
RL-43	298-46			58,900	11,200		
RL-25	298-28	27,300	248	29,500	6,940		
RL-42	298-14			31,000	6,850		
RL-26	298-0	6,570	28	9,200	1,120	4,500	1,560

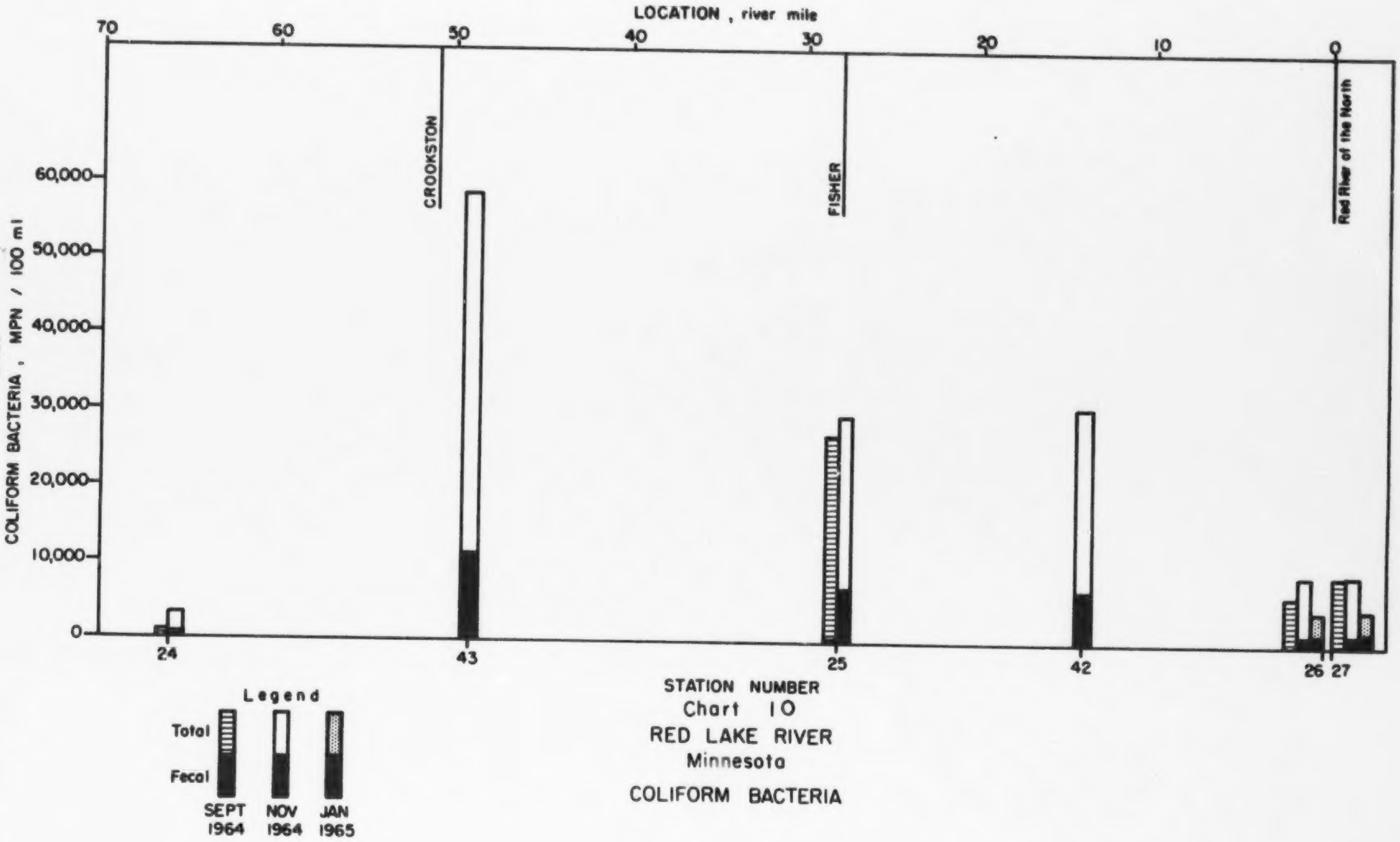


Chart 10
RED LAKE RIVER
Minnesota
COLIFORM BACTERIA

for winter storage. Although the waste discharge from the pond had been held for months, the total coliform content was sufficient to increase the density in the river about 27 times from above the outfall to below it. Total coliform density increased from 918/100 ml above the outfall to 27,300/100 ml below the waste discharge. The fecal coliform density of this waste was quite low, however, causing an increase from 35/100 ml to 248/100 ml in the river. At East Grand Forks the fecal coliform count of 28/100 ml was approximately the same level as that upstream of the pond discharge. The total coliform density of 6570/100 ml was above the State requirements for a water supply. Grand Forks and East Grand Forks have water intakes in the Red Lake River below the waste stabilization pond discharge at Crookston.

In November, with the American Crystal Sugar Company plant at Crookston discharging wastes to the river, the total coliform density increased from 3040/100 ml to 58,900/100 ml, and the fecal coliform density from 670/100 ml to 11,200/100 ml. These represent total bacterial numbers about five times that of September for total coliforms and 93 times greater for fecal coliforms. The sugar plant was the only additional source of waste. The waste effluent from this plant had a mean total coliform density of 6,360,000/100 ml and a fecal coliform density of 1,400,000/100 ml. At East Grand Forks, the total coliform number in November was six times the September value. The total coliform density at East Grand Forks during this phase was 9,200/100 ml and fecal coliform density was 1,120/100 ml. These densities are well in excess of the recommended standard of the States.

During January there were no waste discharges to the Red Lake

River. The total coliform density was in excess of the States' standards for a source of water supply. The fecal coliform density at the monitoring station in East Grand Forks was 1120/100 ml. It is presumed that the extremely low temperatures and the demonstrated persistence of fecal coliform under low temperatures account for this finding, but the source could not be ascertained.

Red River of the North - Grand Forks to International Boundary

The mean bacterial densities observed in this stretch are summarized in Table 12 and also are illustrated in Chart 11. In September the wastes from the municipal waste stabilization ponds at Grand Forks and East Grand Forks were being discharged to the river at R.M. 294. This caused an increase in total coliform density in the Red River from 9050/100 ml to 56,500/100 ml but, as below Crookston, the increase in fecal coliform concentration was comparatively small; from 222/100 ml to 1160/100 ml. Fecal coliforms decreased rapidly in September and at R.M. 236, 58 miles downstream, the mean value was 39/100 ml. The total coliforms, however, remained fairly constant, indicating extensive land runoff. This conclusion is supported by the steadily increasing river flow downstream in this stretch.

The Red River is used as a source of water supply by Oslo, Minnesota, and the densities in the river at this point were 22,800/100 ml and 332/100 ml for total and fecal coliforms respectively. The discharge of untreated sewage at Drayton caused an increase in the fecal coliform density from 39/100 ml to 298/100 ml. Drayton will have a waste stabilization pond system in operation in the near future

Table 12

Coliform Bacteria
Red River of the North
Grand Forks to International Boundary

Station	River Mile	Coliform Densities (MPN/100 ml)					
		Sept.		Nov.		Jan.	
		Total	Fecal	Total	Fecal	Total	Fecal
RR-27	298	9,050	222	9,160	1,440	4,870	1,900
RR-28	292	56,500	1,160	39,800	2,970		
RR-29	286	35,600	890	27,800	1,030		
RR-30	279	23,000	312	21,900	606	17,000	3,700
RR-31	274	22,800	332	19,000	1,100	25,200	2,400
RR-32	254	22,800	51	11,200	195		
RR-34	236	24,400	39	13,100	189	8,850	820
RR-36	208	15,900	298	6,170	476	8,910	800
RR-37	176	2,900	35	3,500	56		
RR-39	158	914	25	2,520	27	4,800	540
FR-33	243-7	4,350	183	1,730	87		
PR-35	222-5	3,870	221	501	70		
PE-38	158-0.5	9,850	400	561	40	3,200	1,000

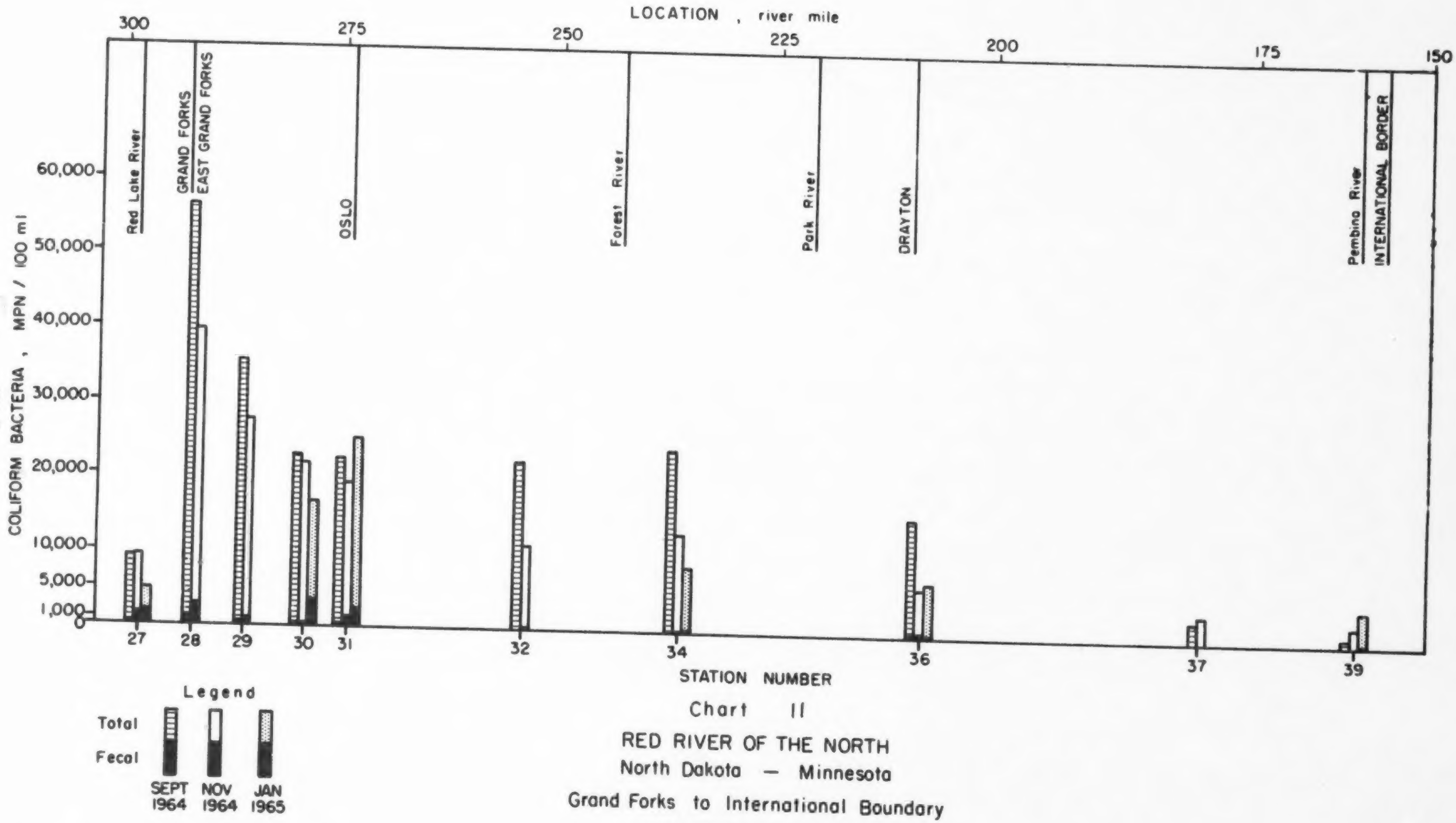


Chart 11

RED RIVER OF THE NORTH
North Dakota — Minnesota
Grand Forks to International Boundary
COLIFORM BACTERIA

so this source will be eliminated. The total and fecal coliforms decreased rapidly below Drayton and laboratory bacterial survival tests of Red River water at Pembina showed that some undetermined constituent of the water inhibited the growth of coliforms. The densities of total and fecal coliforms just before crossing the International Boundary were 914/100 ml and 24/100 ml respectively.

During November, the American Crystal Sugar Company at East Grand Forks and the Rogers Brothers and Pillsbury potato plants in Grand Forks were discharging wastes to the river. In addition, some waste was entering the river from the North Dakota State Mill and a few other commercial establishments connected to this sewer. The municipal waste stabilization ponds also were being discharged. The total coliforms count rose from 9160/100 ml to 39,800/100 ml and the fecal coliforms from 1440/100 ml to 2970/100 ml. The river flow was about two and one-half times that of September, and this represents an increase in total numbers of bacteria in the river of about one and one-half times that of total coliforms and about four times that of fecal coliforms in September. Bacteriological data from each of the industries disclosed that in the wastes from the sugar plant the total and fecal means were 9420/100 ml and 646/100 ml respectively. These are far below the results obtained from the other two sugar plants. This plant provides from seven to eleven days' storage to the wastes before discharge. The corresponding low coliform densities in comparison with the other two sugar plants show the effectiveness of storage in reducing coliform densities. The Pillsbury potato plant uses a lye peeling process which effectively reduces the bacterial contribution to a negligible quantity due to causticity of the lye. The waste from the Rogers Bros. plant had 56,300,000/100 ml and 609,000/100 ml densities for total and fecal coliforms and from the State Mill the densities for total and fecal coliforms were 4,840,000/100 ml and 534,000/100 ml. The wastes from the State Mill sewer are to be connected to the Grand Forks city system in the near future. The largest single contribution of bacterial pollution at Grand Forks was the Rogers Bros. potato plant. It has been agreed that the wastes from the potato plants will be discharged to the Grand Forks municipal system after primary treatment and will be impounded in the municipal lagoons. At Oslo, the densities during this period were 19,000/100 ml and 1100/100 ml respectively. Inflow from the tributary Park and Forest rivers during this period was minor and the fecal coliforms were negligible. At the International Boundary, the densities were 2520/100 ml for total coliforms and 27/100 ml for fecal coliforms.

During January, there was an increase in total coliform density from 4870/100 ml to 17,000/100 ml from above to below sources of waste at Grand Forks-East Grand Forks. The potato plants, during this time, were discharging wastes intermittently as production varied, depending on the supply of potatoes. The State Mill sewer was discharging regularly and the beet sugar plant was not discharging. As in the other stretches of river, the coliform organisms survived for long periods of time under ice cover. At Oslo, the total and fecal coliform averages were the highest of any of the three sampling periods, with values of 25,200/100 ml and 2400/100 ml respectively. At the International Boundary, the total coliform density was 3200/100 ml and the fecal coliform density was 1000/100 ml.

In this stretch of the river, the bacteria at the Oslo water supply intake exceeded the standard for total coliforms during all phases of the survey. The densities of total coliform also exceeded the standard for more than 100 miles downstream from Grand Forks-East Grand Forks under open water conditions. During January, the coliform densities exceeded the standard from Grand Forks to Drayton. Drayton also uses the river as a source of water supply.

PATHOGENIC BACTERIA

Infectious diseases are produced by certain viruses or bacteria and these causative agents are known as pathogenes. It has been an accepted procedure in public health practice to describe deleterious bacteriological quality of water by means of coliform density on the basis that these organisms are indicators of the potential presence of pathogenes. Although the coliform genus is not normally considered pathogenic in itself, fecal coliform bacteria indicate the presence of intestinal or fecal matter which may be a source of intestinal disease-producing organisms or enteric pathogenes. It would, therefore, be appropriate to isolate the disease producers directly wherever possible. If it can be demonstrated that pathogenic micro-organisms are indeed present in comparison with the observed coliform bacteria, both total and fecal, the importance and validity of the coliform group as indicators of pathogenes will be enhanced.

Salmonella, a genus with more than nine hundred species, most of which have been shown to be pathogenic to man and warm-blooded animals, commonly produce serious disease in man. One of the species can produce typhoid fever by ingestion of polluted water. In the past, the isolation of Salmonella from streams or natural waters was deemed impractical because of their relatively low concentrations compared to coliform densities. Now, however, because of the availability of new techniques as well as specific or selective media, the isolation of these pathogenes is possible even at relatively low coliform densities. The principal determination of bacterial pollution of the Red River of the North was based on examination for coliform bacteria. On this survey also, sampling was initiated in certain areas for the detection of pathogenes (Salmonella) and the results of these examinations are given in Table 13.

In September sampling was conducted for only a short distance below the municipal waste outfalls. Three determinations were made: immediately below the Moorhead sewage treatment plant outfall; 12 miles below the outfall at river mile 436, which is one-half day time of travel downstream; and at river mile 426, 22 miles below, or one day time of travel from the outfall. Positive results were obtained at all sampling points. In addition, the same species was identifiable below the outfall and at R. M. 436, 12 miles downstream, thereby implying a strong cause and effect relationship. Twenty-two miles downstream, where the fecal coliform density was a relatively low 2850/100 ml, Salmonella organisms were isolated, indicating persistence even when coliform values are low.

In November, the pathogen sampling program was greatly enlarged and extended. Salmonella were isolated at every sampling point below the sources of waste at Fargo and Moorhead. Significantly, no pathogenic colonies were isolated at a sampling point above the waste

Table 13

Salmonella Organisms

Red River of the North

Date	Station	River Mile	Distance from Waste Source (Miles)	Flow Time (Days)	Total Coli/100ml	Fecal Coli/100ml	Salmonella
Sept. 1964	Moorhead Sewage Treatment Plant	448	0		Not Done	Not Done	S. kentucky
	RR 11	436	12	0.5	250,000	64,500	S. kentucky
	RR 12	426	22	1.0	47,600	2,850	S. saint paul
Nov.1964	RR 9	462	-14		314	49	Absent
	RR 10	441	7	.3	432,000	155,000	S. typhimurium S. braenderup S. reading
	RR 11	436	12	.4	249,000	85,600	S. braenderup S. heidelberg S. reading
	RR 12	426	22	.8	68,000	16,800	S. blockley S. braenderup
	RR 16	386	62	3.0	6,630	1,610	S. heidelberg
	RR 28	292	7	.3	39,800	2,970	S. reading
	RR 29	286	13	.7	27,800	1,030	S. reading S. infantis

Table 13
(Contd.)

Date	Station	River Mile	Distance from Waste Source (Miles)	Flow Time (Days)	Total Coli/100ml	Fecal Coli/100 ml	Salmonella
n.1965	RR 10	441	7	.2	162,000	61,000	S. chester
							S. thompson
							S. oranienburg
							S. st. paul
	RR 11	436	12	.4	83,500	34,000	S. chester
							S. heidelburg
							S. st. paul
							S. enteritidis
							S. typhimurium
	SH 13	428-1	-	-	650	218	Absent
	RR 14	416	32	1.2	18,600	9,170	S. enteritidis
							S. chester
							S. st. paul
							S. thompson
	RR 16	386	62	3.3	7,800	5,160	S. st. paul
							S. enteritidis
							S. thompson
	RR 18	375	73	4.0	6,140	2,950	S. st. paul
							S. thompson

effluents. Most striking is that, at a distance of 62 river miles and over three days time of travel downstream from the sources of waste at Fargo and Moorhead, Salmonella were still present at a fecal count of 1610/100 ml. Colonies were also isolated below the industrial waste discharges at Grand Forks and East Grand Forks. The potato processing plants in Grand Forks discharge domestic sewage to the river. In both river reaches, the same species was found, for several miles dowstream, giving presumptive evidence that their source was the waste discharges.

In January, sampling was conducted under an ice cover averaging two and one-half feet. During this period, Salmonella colonies were isolated 73 river miles downstream and four days time of travel from Fargo-Moorhead under extremely cold river temperature conditions. Salmonella st. paul were isolated at every station below the waste discharges from the municipal plants. The major tributary to the Red River in this stretch, the Sheyenne River, did not yield any pathogenic colonies. Therefore, the origin of pathogenes as far removed downstream as Halstad, Minnesota, is the waste discharges at Fargo and Moorhead.

The 1964 report of the Salmonella Surveillance Committee of the U S. Public Health Service ranks six of the most frequent Salmonella species infecting man and animals in the U. S. in 1963 (see Table 14). Four of the species isolated from the Red River of the North are among these top six for human infection. They are S. typhimurium, S. heidelburg, S. infantis, and S. enteritidis, which rank one, three, five and six, respectively.

The attempt to isolate Salmonella during each of the three

Table 14

Salmonella Types Most Frequently Infecting Man and Animals in 1963

Rank	United States 1963 (1)	
	Man	Animal
1	S. typhimurium	S. typhimurium
2	S. derby	S. heidelberg
3	S. heidelberg	S. infantis
4	S. newport	S. anatum
5	S. infantis	S. montevideo
6	S. enteritidis	S. newport

(1) Source: CDC Salmonella Surveillance Report No. 21, Feb. 3, 1964.

phases of the Red River of the North survey resulted in a 100 percent recovery of these pathogenes wherever they were reasonably expected to be found. Salmonella were not recovered upstream from the principal sources of pollution. Colonies were recovered at all points sampled below the sources of wastes and their extreme persistence is shown by isolation 73 miles and four days time of travel downstream from the Fargo-Moorhead outfalls under ice cover. Four of the Salmonella species isolated from the Red River of the North are among the top six most frequently infecting man in the United States in 1963.

BIOLOGY

AQUATIC LIFE

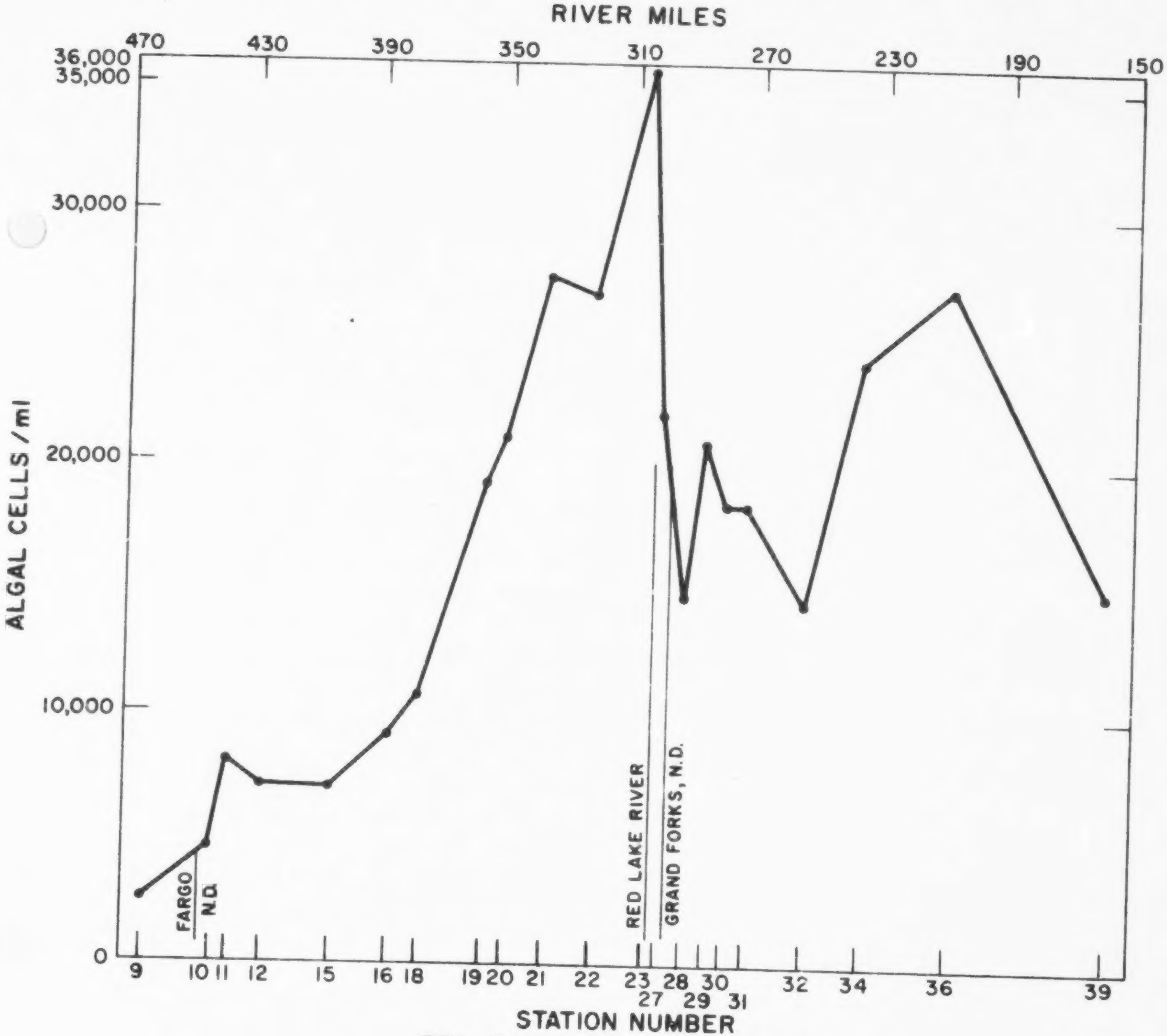
The biological study of the Red River of the North measured the effects of wastes on the aquatic life. Bottom-associated organisms are best adapted to evaluate these effects because they have life cycles that are at least one year in length and thus tend to reflect conditions over a long period of time, and because most bottom organisms have limited methods of locomotion which restrict them to specific stream reaches. Thus, the group of bottom dwelling organisms, considered as a unit, are used to indicate the quality of water flowing over the stream bed. Experience has shown that water quality changes sufficient to alter the structure of the bottom dwelling group will also alter the fish population and other aquatic organisms. Reductions in sensitive bottom forms indicate that the fish population is likewise adversely affected.

Unpolluted water supports a diverse population of bottom organisms and fish, but because of competition and predation, only a few of each kind are usually present. Two different changes occurred in the population of bottom-associated organisms as the result of organic wastes entering the Red River: (1) there was a reduction in the number of kinds of organisms, which resulted from the unnatural covering and blanketing of rocks and the river bottom, by settleable solids and by slime growths produced by the waste discharges, and (2) there was an increase in the numbers of the remaining bottom-associated organisms that resulted from an increased food supply. Three surveys were conducted to evaluate the effect of wastes under different seasonal conditions.

Fargo, North Dakota to Grand Forks, North Dakota

Upstream from Fargo, North Dakota (R.R. 9), the Red River supported five kinds of pollution-sensitive fish food organisms, such as sprawling mayflies, burrowing mayflies, and caddisflies (Appendix). During the September survey, wastes from the Fargo, North Dakota, and the Moorhead, Minnesota, sewage treatment plants eliminated these sensitive organisms for seven miles except for an occasional sprawling mayfly (Chart 13). The kinds of pollution-tolerant organisms increased from two upstream to four downstream from the waste sources.

In November, the combined wastes from the Fargo, North Dakota, and Moorhead, Minnesota, sewage treatment plants and the Moorhead, Minnesota, sugar beet plant eliminated all pollution-sensitive bottom organisms for 17 miles and provided food that increased the pollution-tolerant sludgeworms from 8 to 1,116 per square foot, 17 miles downstream from the waste source (Appendix). No game fish were found to inhabit the reach of river 17 miles downstream from the waste sources in Fargo, North Dakota, area; however, game fish such as northern pike and channel catfish were collected by electro-shocking upstream from Fargo, North Dakota. The absence of sensitive bottom organisms



RED RIVER OF THE NORTH
NORTH DAKOTA — MINNESOTA

TOTAL PHYTOPLANKTON

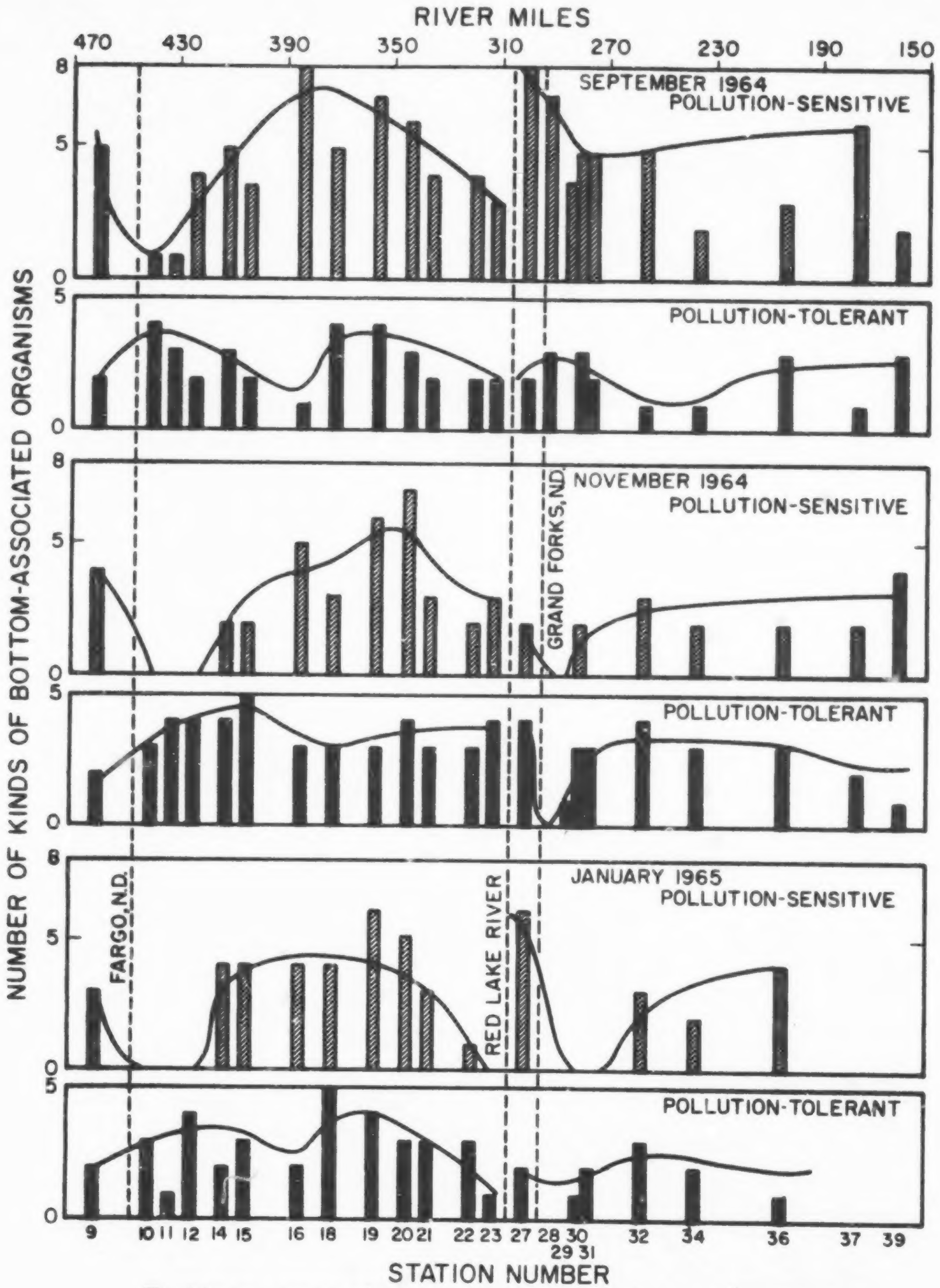
NOVEMBER 1964

Chart 12

and game fish gives vivid testimony to the polluted conditions of the waters in this reach.

Sugar beet wastes reduced the kinds of sensitive organisms from seven in September to two in November in the reach downstream from the confluence of the Sheyenne River with the Red River. Of the two remaining sensitive forms, caddisflies numbered 605 per square foot. This unusually dense population was the result of increased nutrients that provided a ready food supply. These nutrients were from the Fargo-Moorhead area. In addition, organic wastes from the Moorhead, Minnesota, sugar beet plant also increased the population of pollution-tolerant sludgeworms from 2 per square foot in September to 598 per square foot in November, 40 miles downstream from the waste source. The combination of various forms of carbonaceous and nitrogenous material contained in the wastes from the wastes from the Moorhead, Minnesota, sugar beet plant and the Fargo, North Dakota, and Moorhead, Minnesota, sewage treatment plants provided nutrients for the growth of bacterial slimes below Fargo-Moorhead to about Georgetown, Minnesota that covered the stream bed and sensitive fish food organisms, interfering with the normal life processes of the latter.

Under ice cover, sometime between November and January phases of the study, organic wastes that had been discharged by the Moorhead, Minnesota, sugar beet plant settled in a 20 mile slack water reach upstream from Grand Forks, North Dakota, and depleted the dissolved oxygen. This resulted in elimination of all pollution-sensitive mayflies. In November, 3 kinds of mayflies averaging 34 per square foot



Bottom-associated organisms found in Red River of the North-Minnesota and North Dakota-September, November, 1964, and January, 1965.

Chart 13

inhabited this area, but in January none were found.

Grand Forks, North Dakota - Canadian Border

During September, wastes from the Grand Forks, North Dakota sewage lagoons reduced the number of kinds of sensitive fish food organisms from eight upstream to seven two miles downstream from the discharge, and increased the tolerant forms from one to four. However, because of the decreased velocity which caused an increased effect of the discharged organic wastes, the sensitive forms were reduced to three kinds eight miles downstream from the lagoon discharge.

In November, the combined wastes from the Grand Forks, North Dakota, sewage lagoons, East Grand Forks, Minnesota, sugar beet plant, Grand Forks, North Dakota, potato factories, and the Crookston, Minnesota, sugar beet plant eliminated all bottom-associated organisms for at least two miles in the Red River. Six miles downstream from the waste sources only pollution-tolerant sludgeworms were found. Fifteen miles downstream from the waste sources no sensitive fish food organisms were observed, whereas, in September this reach supported five kinds of sensitive fish food organisms. At Oslo, Minnesota, pollution was still evident. Pollution-tolerant sludgeworms had increased from 8 per square foot in September to 608 per square foot in November, following industrial waste discharges. This high population of sludgeworms resulted from the increased organic materials discharged from the sugar and potato factories in the Grand Forks, North Dakota, area.

Bacterial slimes in November covered the stream bed and interfered with the normal life process of the sensitive fish food organisms for 15 miles downstream from the waste sources at Grand Forks, North Dakota.

January results indicated that the decomposition of the organic wastes made conditions so bad near Oslo, Minnesota, that all mayflies were eliminated sometime between November and January.

The phytoplankton (floating algal) populations in the Red River of the North are important because of the problems they create in drinking water supplies. In November, the phytoplankton populations near the Oslo, Minnesota, Drayton and Grand Forks, North Dakota, water treatment plants intakes contained a sufficient density of diatoms (Stephanodiscus hantzschii) to shorten filter runs. Populations of floating algae increased from 2,500 cells per ml upstream from Fargo, North Dakota (R.R. 9), to 35,650 cells per ml near the Grand Forks water intake (R.R. 23) (Chart 12). Upstream from Oslo, Minnesota (R.R. 30), and Drayton, North Dakota (R.R. 34), floating algal populations were 20,750 and 24,250 cells per ml, respectively. All populations contained at least 70 percent of the problem causing diatom. Filter clogging is compounded by the occurrence of mat-forming diatoms on which other organisms collect.

Taste and odor problems in municipal water supplies at Grand Forks, North Dakota, Oslo, Minnesota, and Drayton, North Dakota, probably are caused by the diatom, Stephanadiscus sp.

Nutrients principally responsible for the increased floating algae in the Red River during November between Fargo and Grand Forks, North Dakota, were contained in the wastes from the Fargo-Moorhead area. The Fargo, North Dakota and Moorhead, Minnesota sewage treatment plants in January increased the soluble phosphorus in the river from 0.10 to 0.57 mg per liter as P and the inorganic nitrogen (NH_3-N+NO_3-N +NO_2-N) from 0.8 to 1.8 mg per liter (as N) in the Red River downstream from the respective sources. This increase in concentration of nitrogen and phosphorus was sufficient to promote increased algal productivity during open water periods.

Crookston, Minnesota - Confluence of the Red Lake and Red Rivers

In September, the Red Lake River and the reach of the Red River downstream from the confluence of the Red Lake and Red rivers supported a diverse population of seven kinds of sensitive stoneflies, mayflies, and caddisflies.

Wastes from the Crookston sugar beet plant, in November, eliminated six of these kinds of sensitive fish food organisms from this 49 mile reach of the Red Lake River. These wastes destroyed the population of fish food organisms in both the Red Lake River and in the interstate Red River. In a two mile reach of the Red River just downstream from the confluence with the Red Lake River at Grand Forks, North Dakota, sensitive organisms were reduced to two kinds in November from seven in September by organic wastes and slimes resulting from waste discharges from the Crookston, Minnesota, sugar beet plant. The destruction of the fish food organism population inhabiting the Red River downstream from the waste discharges in Grand Forks-East Grand Forks resulted from combined wastes from Crookston, Minnesota, and the Grand Forks-East Grand Forks area.

Bacterial slimes resulting from the nutrients contained in the wastes from Crookston, Minnesota, blanketed both the stream bed and sensitive organisms in the Red Lake and Red rivers, and thus reduced the natural food for sport fishes.

APPENDIX I

SUMMARY OF SURVEY DATA

Table 1-A

Red River of the North

September 1964

Summary of Field Data

Station		Flow cfs	Temperature °C	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
BD-1	Avg.	5	18.6	8.6	9.1	3.7	2,800	540	48.8	8.8	150	600	31	759
	Max.	9	25.5	10.2	11.4	5.6	160,000	3,300	85.5	12.0	169	700	36	1175
	Min.	1	14.0	8.0	6.5	0.8	1,100	110	33.0	6.0	137	540	23	554
OT-2	Avg.	69	18.4	8.5	9.5	2.7	1,200	177	43.9	9.7	205	238	4	39
	Max.	80	25.0	10.5	10.3	3.8	17,000	2,300	60.3	12.5	213	270	5	62
	Min.	65	15.0	8.1	7.8	0.7	490	70	31.0	7.5	184	210	3	31
OT-3	Avg.	77	18.6	8.6	8.6	2.7	4,820	610	77.0	12.1	205	233	4	38
	Max.	105	23.0	9.2	10.2	4.3	54,000	7,900	100.6	14.5	222	270	4	48
	Min.	61	15.0	8.3	7.4	0.7	490	70	61.5	9.3	182	210	3	32
RR-4	Avg.	85	18.6	8.6	9.7	3.1	4,170	300	61.6	12.7	206	240	5	56
	Max.	110	22.5	9.2	11.5	3.8	11,000	1,300	110.0	18.0	214	420	6	77
	Min.	70	16.0	8.3	9.4	0.7	1,200	80	40.0	9.5	187	210	4	48
RR-5	Avg.	83	18.3	8.5	9.1	3.4	3,920	400	83.5	13.4	214	249	5	63
	Max.	120	22.5	10.4	10.7	4.4	13,000	1,400	119.0	19.0	218	280	6	75
	Min.	70	15.0	8.4	8.0	0.9	1,300	130	54.0	9.0	205	220	4	53
RR-6	Avg.	73	18.7	8.5	7.5	2.5	1,160	43	64.6	9.2	208	264	5	70
	Max.	85	21.0	9.1	9.0	3.2	4,900	> 90	90.0	21.0	218	330	6	82
	Min.	70	16.5	8.1	7.1	0.6	490	< 20	51.0	4.0	202	220	4	59
RR-7	Avg.	71	18.6	8.3	7.6	2.7	4,700	131	72.9	11.2	210	263	5	74
	Max.	80	21.0	8.7	7.9	3.1	13,000	490	84.0	15.5	225	290	7	98
	Min.	65	15.5	8.1	7.1	0.6	1,800	20	58.5	5.5	199	230	4	63
WD-8	Avg.	1	17.9	8.6	7.4	5.3	2,960	295	67.1	13.8	325	394	31	217
	Max.	< 2	24.0	9.0	9.0	7.4	35,000	4,900	81.0	16.5	336	420	33	222
	Min.	< 1	13.0	8.3	5.8	1.6	460	20	58.0	12.0	317	366	29	207
RR-9	Avg.	70	19.1	8.4	8.9	3.4	1,730	236	41.9	7.5	200	266	6	69
	Max.	72	22.0	10.0	10.5	4.8	4,600	1,400	53.0	11.0	231	320	10	98
	Min.	66	15.0	8.0	7.8	0.6	790	20	23.5	3.5	206	226	5	41
RR-10	Avg.	75	19.5	8.1	4.4	9.8	865,000	233,000	61.4	14.1	203	268	17	98
	Max.	80	23.5	8.6	6.4	12.6	2,800,000	790,000	72.0	16.5	209	310	21	116
	Min.	70	15.5	7.9	2.0	2.8	79,000	33,000	44.0	12.0	197	220	11	86
RR-11	Avg.	76	19.3	8.3	5.9	8.5	250,000	64,500	111.8	22.1	209	306	20	112
	Max.	85	24.5	9.7	14.5	10.0	920,000	540,000	127.0	24.0	248	340	43	157
	Min.	70	16.0	7.8	1.5	1.7	500	< 200	96.5	20.0	202	270	11	100

Table 1-A (Cont.)

Red River of the North

September 1964

Summary of Field Data

Station		Flow cfs	Temperature °C	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
RR-12	Avg.	81	18.4	8.2	8.1	7.6	47,600	2,850	141.1	20.4	235	315	46	151
	Max.	95	23.0	10.2	11.6	8.1	220,000	11,000	201.0	32.5	240	350	54	164
	Min.	70	15.0	7.7	6.1	1.5	33,000	1,100	116.5	20.0	230	280	39	135
SH-13	Avg.	67	17.6	8.3	8.8	4.8	68,000	1,530	134.6	23.4	258	309	73	189
	Max.	110	22.0	8.8	10.6	5.6	280,000	7,900	194.0	28.0	271	340	91	280
	Min.	55	14.0	8.1	7.3	1.1	22,000	700	82.0	17.0	237	270	59	160
RR-14	Avg.	182	17.7	8.5	8.3	6.4	16,800	1,510	142.4	22.4	243	309	40	150
	Max.	225	22.0	10.1	10.3	7.2	54,000	3,300	193.0	25.0	251	340	46	161
	Min.	160	15.0	8.1	6.5	1.1	3,300	490	111.0	19.0	235	270	35	137
RR-15	Avg.	185	18.1	8.4	10.0	5.9	4,590	500	152.2	26.0	244	307	40	149
	Max.	225	23.5	8.7	13.1	6.9	11,000	1,300	202.0	37.0	252	340	46	163
	Min.	160	15.0	8.2	6.9	1.6	2,300	130	81.0	17.0	233	270	34	135
RR-16	Avg.	187	18.3	8.7	12.4	7.0	990	126	96.0	22.3	237	303	39	146
	Max.	225	21.5	9.7	19.4	9.0	3,300	790	118.0	28.0	252	340	48	166
	Min.	160	15.0	8.3	5.8	0.9	230	20	75.0	17.5	205	270	20	116
WH-17	Avg.	29	17.5	8.5	8.4	1.8	12,450	4,550	30.5	5.9	250	286	4	63
	Max.	33	20.0	10.2	9.3	2.5	35,000	13,000	54.0	10.0	262	320	5	70
	Min.	25	16.0	8.1	7.1	0.7	2,200	230	18.3	3.3	234	230	4	59
RR-18	Avg.	218	18.1	8.7	14.0	7.0	1,970	117	81.0	21.9	239	301	35	136
	Max.	255	22.0	9.2	18.0	8.9	13,000	330	111.0	27.0	246	330	41	153
	Min.	192	15.0	8.3	10.1	2.5	330	20	53.0	14.0	231	270	29	118
RR-19	Avg.	225	17.5	8.8	11.7	8.3	2,200	26	82.9	22.8	223	284	35	138
	Max.	260	20.5	9.0	15.1	11.5	7,900	110	102.0	26.0	230	310	38	153
	Min.	200	15.0	8.5	8.1	6.3	330	< 20	74.0	18.0	214	260	30	122
RR-20	Avg.	232	17.6	8.8	9.9	6.7	1,260	23	76.2	21.8	218	291	38	141
	Max.	260	20.5	9.1	11.6	10.1	4,900	50	106.0	27.2	231	330	43	156
	Min.	200	14.5	8.5	7.7	5.6	490	< 20	63.5	18.8	205	250	35	126
RR-21	Avg.	297	17.4	8.7	9.0	5.8	13,300	82	114.9	22.5	227	280	32	119
	Max.	500	21.0	8.9	10.2	6.9	160,000	1,720	231.0	37.5	303	350	44	142
	Min.	230	14.5	8.5	8.1	4.4	1,300	< 20	71.5	11.5	200	230	14	53
RR-22	Avg.	325	17.8	8.7	8.1	4.5	710	43	67.7	14.7	195	258	31	112
	Max.	490	20.5	9.0	10.2	7.1	17,200	1,300	96.8	19.6	234	320	43	143
	Min.	220	14.0	8.6	6.3	3.3	140	< 20	38.0	10.5	124	180	17	68

Table 1-A (Cont.)
Red River of the North
September 1964
Summary of Field Data

Station		Flow cfs	Temperature °C.	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria		Suspended Solids		Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
							Total MPN/100 ml	Fecal MPN/100 ml	Total mg/1	Volatile mg/1				
RR-23	Avg.	333	18.7	8.3	6.9	3.2	1,160	55	72.2	11.9	183	251	27	101
	Max.	500	21.0	9.2	8.0	4.0	4,900	330	88.0	14.0	232	280	39	126
	Min.	220	16.0	7.8	6.3	0.9	200	< 20	60.5	10.0	105	170	11	61
RL-24	Avg.	247	18.2	8.5	9.2	1.7	918	35	34.1	8.3	177	243	4	69
	Max.	300	22.0	8.8	9.8	2.5	4,900	80	66.8	15.6	192	310	5	109
	Min.	190	15.0	8.3	8.1	1.0	220	< 20	17.2	3.6	165	210	3	48
RL-25	Avg.	254	18.2	8.3	8.8	2.1	27,300	248	55.8	9.8	171	230	4	81
	Max.	340	21.0	8.5	9.8	2.8	[illegible]	22,100	70.0	14.4	189	270	7	116
	Min.	200	16.0	8.0	7.8	1.6	4,900	20	43.2	4.0	164	190	2	51
RL-26	Avg.	277	18.4	8.3	8.5	2.6	6,570	28	48.8	11.0	172	248	6	91
	Max.	380	21.5	8.6	10.9	4.4	23,000	90	56.8	14.0	185	260	7	122
	Min.	200	16.0	8.1	7.1	1.7	2,210	< 20	43.4	6.4	145	210	4	66
RR-27	Avg.	607	17.7	8.3	7.4	2.3	9,050	222	63.4	12.0	179	245	17	104
	Max.	383	19.5	8.6	8.1	2.6	79,000	1,410	78.0	14.5	210	200	26	177
	Min.	419	15.0	7.7	6.9	1.9	2,780	< 20	50.4	8.0	137	290	8	53
RR-28	Avg.	625	18.0	8.3	8.2	3.6	56,500	1,160	90.1	14.4	134	266	30	107
	Max.	880	21.0	8.5	8.6	6.9	[illegible]	17,200	140.0	19.2	213	310	39	127
	Min.	430	16.0	8.0	7.7	2.4	17,200	200	58.5	10.4	142	210	20	75
RR-29	Avg.	648	18.3	8.4	8.2	3.2	35,600	890	192.3	23.8	188	271	32	111
	Max.	890	21.3	8.7	9.3	3.1	172,000	4,600	371.0	35.5	218	320	40	127
	Min.	450	16.0	8.0	7.3	2.0	4,600	220	81.2	13.5	142	220	22	75
RR-30	Avg.	662	17.6	8.4	8.5	3.0	23,000	312	98.0	15.8	190	279	31	113
	Max.	900	21.0	8.6	9.2	3.6	79,000	1,300	177.0	20.0	215	310	37	132
	Min.	470	15.0	8.2	7.7	2.4	7,900	130	75.0	10.5	140	220	23	77
RR-31	Avg.	698	18.0	8.3	8.5	2.5	22,800	332	72.5	14.6	193	283	60	127
	Max.	910	21.0	8.6	9.5	3.1	160,000	1,300	92.4	20.5	214	340	73	143
	Min.	500	16.5	8.0	8.1	1.7	1,720	80	63.0	8.0	147	240	50	97
RR-32	Avg.	711	17.9	8.4	9.0	2.6	22,800	51	101.5	15.6	201	297	56	132
	Max.	910	21.5	8.6	10.1	3.3	54,200	180	142.0	18.5	215	330	74	142
	Min.	530	16.0	8.1	8.2	2.2	4,900	< 20	86.0	12.0	173	250	44	110
FR-33	Avg.	6	16.6	8.6	10.6	11.2	4,350	183	82.5	25.4	182	642	1500	565
	Max.	8	24.5	8.7	12.3	17.1	49,000	790	126.0	32.0	213	750	1720	1030
	Min.	4	12.0	8.5	8.7	7.3	1,300	20	58.8	20.8	163	530	1355	462

Table 1-A (Cont.)

Red River of the North

September 1964

Summary of Field Data

Station		Flow cfs	Temperature °C.	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
RR-34	Avg.	739	17.4	8.4	8.8	2.2	24,400	39	116.0	16.0	205	305	88	140
	Max.	930	20.5	8.7	9.6	2.7	160,000	130	160.0	20.0	215	330	182	152
	Min.	590	16.0	8.0	8.1	1.6	7,000	< 20	101.0	13.0	192	270	42	132
PR-35	Avg.	8	16.9	8.8	21.0	20.2	3,870	221	56.4	29.1	193	873	3,996	344
	Max.	11	20.0	9.0	31.4	> 32.7	24,000	700	98.5	34.5	250	1,000	4,850	990
	Min.	5	12.5	8.5	11.7	8.1	1,720	50	34.0	24.0	155	750	1,805	791
RR-36	Avg.	766	16.9	8.3	8.9	1.9	15,900	298	103.7	17.3	204	312	117	146
	Max.	956	20.0	8.5	9.4	2.2	34,800	1,410	144.0	24.0	215	350	150	161
	Min.	638	15.5	8.0	8.5	0.7	7,000	50	71.0	10.5	191	270	96	137
RR-37	Avg.	800	17.2	8.4	9.4	1.9	2,900	35	98.3	16.3	202	315	106	144
	Max.	930	20.0	8.7	10.2	2.9	14,100	110	161.0	24.5	220	350	140	153
	Min.	720	15.5	8.2	9.2	0.8	490	< 20	45.0	8.0	180	270	71	132
PE-38	Avg.	113	16.2	8.3	8.[illegible]	1.6	9,850	400	71.2	14.0	194	281	13	164
	Max.	160	19.0	8.5	9.8	2.4	92,000	7,900	122.0	19.6	236	320	19	175
	Min.	80	14.0	8.1	8.0	1.2	2,210	130	35.5	10.0	156	220	9	116
RR-39	Avg.	868	16.5	8.5	9.0	1.7	914	25	102.0	16.5	197	310	100	141
	Max.	1,040	19.5	8.6	9.5	2.8	4,600	130	176.0	24.0	208	340	140	153
	Min.	720	14.5	8.3	8.5	1.3	230	< 20	46.4	9.6	183	270	63	129
OT-40	Avg.		18.1	8.2	8.0	1.7	210	24	7.4	3.1	171	203	3	2
	Max.		20.0	8.5	8.5	2.0	490	70	9.9	4.0	173	220	4	3
	Min.		17.0	7.9	7.6	0.7	90	< 20	5.7	1.3	168	190	2	0
OT-41	Avg.		18.8	8.[illegible]	8.1	3.0	16,200	4,760	15.4	5.6	197	233	5	11
	Max.		23.0	8.6	9.9	5.3	160,000	54,000	22.6	8.3	215	270	8	18
	Min.		16.0	8.0	7.4	1.1	3,300	490	11.0	3.9	178	200	4	5

Table 1-3

Red River of the North

November 1964

Summary of Field Data

Station		Flow cfs	Temperature °C.	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
RR-9	Avg.	234	7.7	7.9	10.8	2.0	314	49	40	9	204	235	5	24
	Max.	280	10.0	8.3	11.4	2.6	2,300	130	48	26	221	250	9	36
	Min.	200	5.0	7.6	10.2	1.6	140	< 20	32	3	174	220	4	9
RR-10	Avg.	230	8.9	7.8	5.8	15.4	432,000	155,000	53	15	216	246	9	34
	Max.	275	12.0	8.1	7.1	20.0	1,100,000	490,000	73	20	231	280	13	53
	Min.	200	7.5	7.6	4.7	9.8	230,000	70,000	32	11	206	220	8	12
RR-11	Avg.	229	8.3	7.8	3.5	10.7	249,000	35,600	44	14	220	246	9	33
	Max.	270	11.0	8.1	5.3	15.7	790,000	230,000	50	18	234	260	20	50
	Min.	200	6.0	7.6	2.0	7.5	33,000	23,000	40	11	201	230	7	10
RR-12	Avg.	292	8.1	7.9	4.8	6.3	68,000	16,300	26	10	235	271	19	94
	Max.	320	10.0	8.1	6.1	7.3	240,000	49,000	38	19	280	290	22	237
	Min.	270	6.0	7.7	3.6	4.6	33,000	7,000	12	3	220	260	8	40
SH-13	Avg.	64	6.8	8.1	11.5	3.4	1,410	203	29	9	275	325	43	139
	Max.	95	10.5	8.3	12.5	4.0	4,900	1,300	42	16	291	350	56	217
	Min.	50	3.5	7.8	10.4	2.9	330	20	18	4	232	210	16	171
RR-14	Avg.	318	7.8	7.9	6.5	4.2	27,100	8,160	20	10	251	287	20	77
	Max.	340	9.0	8.2	7.4	5.3	49,000	17,000	26	21	289	310	51	101
	Min.	280	5.0	7.7	5.7	3.6	7,900	3,300	15	4	234	270	16	42
RR-15	Avg.	319	7.8	7.9	8.0	4.4	20,300	5,310	20	8	249	285	17	78
	Max.	350	10.0	8.2	9.4	5.5	490,000	23,000	25	15	281	310	19	94
	Min.	280	5.0	7.6	7.1	3.3	7,900	1,300	16	2	234	260	15	55
RR-16	Avg.	316	7.5	8.0	10.0	4.8	6,630	1,610	34	10	250	284	18	78
	Max.	350	10.5	8.3	12.0	6.5	24,000	4,900	59	14	274	300	20	98
	Min.	275	5.0	7.7	8.8	3.4	1,700	500	24	4	233	270	16	45
WM-17	Avg.	67	7.0	8.1	11.0	1.1	3,670	1,820	8	4	270	298	3	33
	Max.	100	9.5	8.3	12.4	1.3	17,000	4,600	13	6	281	350	4	42
	Min.	50	5.0	7.0	9.5	0.8	700	170	2	3	253	280	2	10
RR-18	Avg.	380	7.2	8.1	11.1	4.4	4,180	722	59	13	260	289	15	68
	Max.	440	10.0	8.4	12.7	5.7	17,000	3,300	98	19	277	320	16	84
	Min.	347	5.0	7.8	9.5	3.6	790	170	35	5	253	270	13	35
RR-19	Avg.	378	7.1	8.1	12.2	4.4	2,650	780	46	13	255	285	15	68
	Max.	430	9.5	8.5	13.7	5.4	7,900	3,300	75	18	261	290	16	84
	Min.	350	5.0	7.9	10.6	3.5	700	270	32	8	248	280	7	37

Table 1-8 (Cont.)

Red River of the North

November 1964

Summary of Field Data

Station		Flow cfs	Temperature °C.	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
RR-20	Avg.	384	6.8	8.2	12.9	4.6	1,130	250	43	13	255	286	16	73
	Max.	440	9.5	8.5	14.9	5.3	14,000	790	62	16	263	300	14	93
	Min.	355	5.0	7.9	11.0	3.8	330	20	34	4	246	270	17	43
RR-21	Avg.	401	6.8	8.3	13.6	4.7	1,410	247	44	13	257	293	15	73
	Max.	440	10.0	8.7	16.0	5.9	13,000	1,700	62	19	269	300	17	93
	Min.	370	5.0	8.0	12.1	3.8	330	20	30	3	247	280	14	44
RR-22	Avg.	401	7.0	8.4	14.8	4.8	125	20	27	12	257	295	15	74
	Max.	440	9.0	8.8	16.7	6.0	790	20	33	14	270	310	17	92
	Min.	370	5.5	8.0	12.9	3.9	20	< 20	20	7	246	290	14	52
RR-23	Avg.	401	6.7	8.7	16.2	5.4	48	< 20	41	14	256	293	15	73
	Max.	440	9.0	9.0	18.6	6.5	330	40	54	20	277	300	17	95
	Min.	370	5.0	8.5	13.9	4.1	< 20	< 20	31	6	203	280	9	52
RL-24	Avg.	1063	6.1	8.0	12.0	2.1	3,040	670	28	8	191	239	2	70
	Max.	1210	10.0	8.3	12.6	2.9	11,000	2,300	40	11	265	280	16	90
	Min.	830	4.0	7.7	11.3	1.3	490	130	16	3	170	220	1	39
RL-25	Avg.	1086	6.3	8.0	10.7	3.4	29,500	6,940	29	10	176	245	2	80
	Max.	1,230	9.0	8.3	11.7	4.3	49,000	33,000	34	12	184	260	2	107
	Min.	880	4.0	7.7	10.0	2.4	7,000	1,300	20	6	171	220	1	54
RL-26	Avg.	1115	6.3	8.3	10.6	2.6	9,200	1,120	27	10	185	257	4	87
	Max.	1230	8.5	8.9	11.2	3.2	> 160,000	7,900	37	18			18	157
	Min.	910	4.5	8.1	9.8	1.9	790	170	17	4			1	52
RR-27	Avg.	1512	6.1	8.6	12.2	3.4	9,160	1,440	34	10	199	271	6	84
	Max.	1610	8.0	9.3	12.9	4.7	33,000	5,000	45	18	209	330	12	133
	Min.	1320	4.5	8.3	11.2	2.7	2,780	490	23	4	193	240	3	54
RR-28	Avg.	1515	6.4	8.5	11.6	6.0	39,800	2,970	59	14	203	271	8	88
	Max.	1610	8.0	8.7	12.6	10.3	160,000	23,000	139	22	211	300	15	138
	Min.	1320	4.0	8.3	11.0	3.8	7,900	790	34	8	195	260	4	57
RR-29	Avg.	1525	6.6	8.5	11.1	5.2	27,800	1,030	45	12	204	278	8	85
	Max.	1620	9.0	8.7	12.3	8.2	240,000	5,000	82	15	215	330	12	146
	Min.	1340	5.0	8.2	10.1	3.8	4,900	211	26	7	195	260	4	30
RR-30	Avg.	1525	6.4	8.5	11.2	4.8	21,900	606	42	12	201	271	7	86
	Max.	1620	8.0	8.6	11.9	7.6	54,200	4,900	55	19	207	310	11	138
	Min.	1350	5.0	8.2	10.5	3.6	7,900	200	29	7	194	260	3	55

Table 1-B (Cont.)

Red River of the North

November, 1964

Summary of Field Data

Station		Flow cfs	Temperature °C.	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
RR-31	Avg.	1545	6.0	8.4	11.2	4.6	19,000	1,100	32	11	210	285	13	94
	Max.	1640	7.0	8.7	12.7	7.4	49,000	7,900	44	16	318	300	18	140
	Min.	1380	5.0	8.2	10.3	3.6	4,900	< 200	22	6	195	260	2	57
RR-32	Avg.	1561	6.4	8.5	11.4	4.9	11,200	195	45	12	204	278	14	95
	Max.	1660	8.0	8.8	12.1	8.6	34,800	330	56	18	210	320	19	134
	Min.	1360	5.0	8.2	10.1	3.8	1,720	110	37	6	194	260	7	63
FR-33	Avg.	11	5.4	8.4	12.4	9.1	1,730	87	79	22	214	784	1443	533
	Max.	56	10.0	8.7	14.5	12.4	13,000	330	98	28	233	970	2070	725
	Min.	0	3.0	8.2	10.3	6.0	790	20	58	14	199	650	990	434
RR-34	Avg.	1591	5.7	8.5	11.6	4.4	13,100	189	53	11	221	285	49	112
	Max.	1700	7.0	8.7	12.2	5.4	49,000	700	65	16	337	330	61	158
	Min.	1300	4.5	8.2	10.9	3.4	3,300	< 20	46	3	201	220	13	67
PR-35	Avg.	7	4.4	8.5	15.1	6.0	501	70	23	12	274	1007	3314	802
	Max.	8	10.5	8.9	19.6	8.9	1,300	300	36	16	345	1350	5725	977
	Min.	7	0	8.2	9.3	4.0	230	< 20	15	6	207	510	1505	340
RR-36	Avg.	1611	5.8	8.5	11.8	4.2	6,170	476	55	11	216	307	67	121
	Max.	1730	7.5	8.8	12.8	5.3	24,000	2,300	62	16	341	380	89	173
	Min.	1180	4.5	8.3	11.2	3.4	< 2,000	< 20	44	5	198	270	50	74
RR-37	Avg.	1562	6.0	8.5	11.7	3.7	3,500	56	46	10	214	299	58	118
	Max.	1680	7.5	8.8	12.3	4.5	17,200	830	64	19	277	330	82	153
	Min.	1160	5.0	8.4	11.1	2.9	1,300	< 20	34	6	199	270	23	74
PE-38	Avg.	50	5.0	8.5	12.1	1.8	561	40	25	7	258	367	25	194
	Max.	52	7.5	8.8	13.0	2.4	2,300	80	32	12	279	400	90	210
	Min.	48	3.0	8.3	11.1	0.9	220	< 20	18	3	204	250	9	158
RR-39	Avg.	1524	5.7	8.6	11.7	3.5	2520	27	51	12	210	303	51	127
	Max.	1650	7.0	8.8	12.4	4.3	10,900	70	70	17	271	370	85	193
	Min.	1150	5.0	8.4	11.1	2.2	490	< 20	39	8	[illegible]	270	18	86
RL-42	Avg.	1106	6.3	7.9	10.6	3.1	31,000	6,850	31	8	175	260	3	86
	Max.	1230	9.0	8.3	11.4	4.3	79,000	14,000	38	16	182	330	10	135
	Min.	880	5.0	7.7	9.9	2.4	4,900	2,300	24	3	151	230	2	60
RL-43	Avg.		6.6	7.9	11.2	5.6	58,900	11,200	31	9	178	248	2	76
	Max.		10.0	8.3	12.3	7.6	540,000	33,000	38	14	184	280	4	93
	Min.		10.4	7.7	10.5	4.4	17,000	4,900	23	3	170	230	2	53

Table 1-C

Red River of the North

January 1965

Summary of Field Data

Station		Flow cfs	Temperature °C	pH	Dissolved Oxygen mg/1	5-Day 20° C. BOD mg/1	Coliform Bacteria Total MPN/100 ml	Coliform Bacteria Fecal MPN/100 ml	Suspended Solids Total mg/1	Suspended Solids Volatile mg/1	Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
RR- 9	Avg.	189	0	8.0	12.7	1.8	530	450	8	4	267	281	5	31
	Max.	195	0	8.3	13.1	2.5	1,700	1,700	20	10	289	330	6	35
	Min.	185	0	7.9	12.3	1.0	230	220	5	0	249	260	4	29
RR-10	Avg.	194	0	8.1	11.1	8.4	162,000	61,000	8	5	259	259	9	40
	Max.	200	0	8.2	11.7	18.9	540,000	140,000	15	5	283	300	13	41
	Min.	190	0	7.9	10.2	4.9	79,000	22,000	5	5	243	250	7	36
RR-11	Avg.	190	0	8.0	9.8	7.8	83,500	34,000	11	8	258	273	10	39
	Max.	195	0	8.1	10.6	17.4	230,000	130,000	35	15	268	290	20	45
	Min.	185	0	7.9	8.8	3.3	33,000	23,000	5	5	246	260	7	34
SH-13	Avg.	69	0	7.8	4.0	2.0	650	218	11	5	315	348	55	153
	Max.	75	0	8.0	6.0	3.4	4,900	1,700	20	5	372	410	80	170
	Min.	62	0	7.7	1.5	1.1	70	40	5	0	254	330	45	135
RR-14	Avg.	265	0	7.9	5.7	3.7	18,600	9,170	8	4	286	305	22	64
	Max.	270	1.0	8.1	6.7	8.6	33,000	23,000	20	10	310	330	45	88
	Min.	260	0	7.7	4.2	1.1	7,000	3,300	0	0	276	290	17	33
RR-15	Avg.	262	0	7.9	5.9	2.2	19,100	10,800	8	5	280	298	18	54
	Max.	265	0	8.0	6.3	2.7	35,000	24,000	10	5	283	300	19	72
	Min.	260	0	7.8	5.6	1.9	4,900	4,900	5	5	276	290	17	29
RR-16	Avg.	260	0	7.9	5.0	2.7	7,800	5,160	5	5	282	303	21	79
	Max.	265	0	8.1	8.5	5.0	24,000	13,000	10	5	302	320	25	88
	Min.	255	0	7.7	3.4	1.9	3,300	2,300	0	0	274	300	17	70
WM-17	Avg.	33	0	7.7	6.9	1.4	10,800	3,780	8	7	358	365	2	38
	Max.	34	0	7.8	7.8	2.8	35,000	7,900	10	10	362	370	3	40
	Min.	32	0	7.4	6.5	0.8	3,300	1,300	5	5	354	360	2	36
RR-18	Avg.	292	0	7.9	4.9	2.7	6,140	2,950	11	6	291	309	19	75
	Max.	292	0	8.1	7.4	5.4	13,000	4,900	25	10	310	330	22	86
	Min.	291	0	7.6	3.6	1.9	2,300	1,300	5	5	279	300	17	69
RR-19	Avg.	295	0	7.8	3.1	3.9	9,900	3,930	8	5	290	312	18	72
	Max.	295	1.0	7.9	4.0	8.1	17,000	7,900	10	5	293	320	21	80
	Min.	295	0	7.6	2.4	1.6	7,000	1,700	5	5	286	300	14	67
RR-20	Avg.	300	0	7.8	3.7	3.2	3,520	1,970	11	5	296	319	21	76
	Max.	300	0	8.0	4.2	8.1	7,000	4,600	25	5	314	340	24	89
	Min.	300	0	7.7	2.5	1.0	1,700	790	5	5	280	310	17	72
RR-21	Avg.	312	0	7.9	4.7	2.7	4,760	2,600	13	3	302	329	20	78
	Max.	315	0	8.0	8.4	8.2	11,000	4,900	20	10	339	380	25	94
	Min.	305	0	7.7	2.5	1.2	1,800	1,700	10	0	287	310	16	74

Table 1-C (Cont.)

Red River of the North

January 1965

Summary of Field Data

Station		Flow cfs	Temperature °C	pH	Dissolved Oxygen mg/1	5-Day 20°C. BOD mg/1	Coliform Bacteria		Suspended Solids		Alkalinity mg/1	Hardness mg/1	Chlorides mg/1	Sulfates mg/1
							Total MPN/100 ml	Fecal MPN/100 ml	Total mg/1	Volatile mg/1				
RR-22	Avg.	315	0	7.8	3.4	3.3	1,600	820	7	3	295	320	21	78
	Max.	315	0	7.9	7.1	7.7	3,300	1,700	10	5	299	320	22	80
	Min.	315	0	7.7	0.9	1.3	790	490	5	0	287	320	19	74
RR-23	Avg.	315	0	7.8	3.0	1.5	1,280	590	6	3	291	317	20	75
	Max.	320	0	7.9	5.0	2.2	3,300	1,100	10	5	300	320	22	80
	Min.	310	0	7.6	2.6	0.8	490	590	0	0	287	310	17	62
GFWP	Avg.	-	2.8	7.8	2.4	1.4	1,100	340	6	5	293	315	20	76
	Max.	-	4.5	7.9	2.6	1.6	4,900	790	10	5	295	320	22	82
	Min.	-	1.6	7.7	2.0	1.1	300	170	5	5	288	310	18	69
RL-26	Avg.	647	0	8.0	11.6	1.3	4,500	1,560	10	5	183	208	2	15
	Max.	655	0	8.3	12.4	2.0	11,000	2,300	10	5	199	210	3	16
	Min.	630	0	7.9	11.2	0.6	2,300	790	10	5	130	200	1	14
RR-27	Avg.	955	1	7.9	8.8	2.2	4,870	1,900	13	5	228	246	7	38
	Max.	970	0	8.1	10.0	2.9	11,000	4,900	20	5	231	250	8	42
	Min.	940	1	7.6	8.4	1.8	2,300	1,100	10	5	221	240	7	33
RR-30	Avg.	947	0	7.9	10.8	1.7	17,000	3,700	7	5	230	248	7	40
	Max.	965	0	7.9	11.2	2.6	24,000	9,400	10	5	234	250	8	44
	Min.	935	0	7.7	10.4	1.2	9,400	1,300	5	5	224	240	7	35
RR-31	Avg.	940	0	7.9	10.8	1.8	25,200	2,400	8	2	229	246	10	41
	Max.	950	0	8.0	11.7	2.2	160,000	4,900	10	5	233	250	10	43
	Min.	935	0	7.7	10.3	1.4	9,000	1,300	5	0	222	240	9	37
RR-34	Avg.	928	0	7.9	10.4	1.7	8,850	820	8	7	229	246	11	43
	Max.	935	0	8.1	10.7	2.7	14,000	7,900	10	10	236	260	12	41
	Min.	925	0	7.7	10.2	1.0	7,900	400	5	5	224	220	10	45
RR-36	Avg.	922	0	7.9	10.2	1.2	8,910	800	10	8	234	258	32	49
	Max.	930	0	8.0	10.5	1.5	17,000	2,300	10	10	236	270	36	54
	Min.	920	0	7.6	10.1	0.8	4,900	330	10	5	232	260	29	44
P.Hi. RL-38	Avg.	5.0	0	7.8	6.6	1.6	3,200	1,000	12	8	364	518	19	160
	Max.	5.2	0	8.0	6.9	2.9	13,000	3,300	20	10	395	530	20	170
	Min.	4.9	0	7.6	6.1	0.4	490	230	5	5	296	500	19	153
RR-39	Avg.	898	0	7.9	11.9	1.3	4,800	540	7	5	238	270	38	54
	Max.	910	0	8.1	12.5	1.9	7,900	1,100	10	5	244	270	40	58
	Min.	.880	0	7.6	11.6	0.8	1,800	230	5	5	232	270	37	48

Table 2-A

Summary of Industrial Waste Samples

Red River of the North

	Flow (MGD)	Temp. °C.		Ash Flume Flow	Ash Flume Temp. °C.	pH			Suspended Solids Determination				Phenols (mg/1)		5-day 20°C. BOD			Coliform Data			
									Influent		Effluent							Influent		Effluent	
		Influent	Effluent			Influent	Effluent	Ash Flume	Total	Volatile	Total	Volatile	Influent	Effluent	Influent	Effluent	Ash Flume	Total	Fecal	Total	Fecal
	Moorhead Sugar Plant																				
	3.0	46	17			-			7830	1010	200	80			1515	506		1,600,000	1,600,000	1,700,000	1,700,000
	3.0	47	14.5			8.4	7.1								980	531		230,000	33,000	3,500,000	3,500,000
	-	46	13	-	37	8.5	7.2	9.0	3500	620	126	66			420	332	25.0	330,000	79,000	790,000	790,000
	2.2	47	16		43	8.3	7.3	8.8							900	425	58.5	490,000	[illegible]1,000	1,300,000	790,000
Avg.	2.7	46.5	15	-	40	8.4	7.2	8.9	5566	815	163	73			954	449	42				
	East Grand Forks Sugar Plant																				
	5.0	36	8.5			8.7	7.6		4890	264	76.5	48.0			285	192		3,480,000	230,000	7,900	790
	4.75	37	9.5			9.2	8.0		4960	612	50.0	33.0	18.0	5.0	249	166		9,200,000	1,720,000	22,100	1,300
	4.75	39	9.5	-	-	8.7	7.8		5810	868	55.0	43.5			346	182		4,900,000	230,000	22,100	2,300
	4.75	38	7.5			8.7	7.9		4270	608	43.0	29.5			328	170		3,450,000	230,000	92,000	2,120
	4.75	36	7.0			9.0	8.0		3520	516	43.5	26.0	15.2	9.6	246	108		6,300,000	110,000	22,100	1,720
Avg.	4.8	37.5	8.5	-	-	8.9	7.9		4690	578	53.6	36	16.6	7.3	291	164					
	Crookston Sugar Plant																				
	3.25	40	13.5	.029	25	7.9	7.4	7.4	-	-	-	-			275	388	-	1,100,000	70,000	3,500,000	1,300,000
	-	-	-	-	-	8.8	7.6	7.7							388	606	> 157	1,700,000	49,000	3,500,000	1,300,000
	3.30	40	10	.015	25	8.4	7.5	7.9	-	-	42	20			332	506	> 175	1,300,000	130,000	3,500,000	1,100,000
	3.30	43	8	-	22	8.9	7.4	7.6							419	612	75.8	170,000	33,000	790,000	790,000
	-	44		.097	22	8.9	7.5	8.1	5330	660	90	50			356	600	195	49,000	22,000	5,400,000	3,500,000
Avg.	3.28	42	10.5	.047	23.5	8.7	7.5	7.7	5330	660	66	35			354	542					

Table 2-A (Cont.)

Industrial Wastes
Bacteriological Results

Red River of the North

	ACS - Total	Moorhead Fecal	ACS - Total	E.Grand Forks Fecal	ACS - Total	Crookston Fecal	Roger Bros. Potato Total	Roger Bros. Potato Fecal	Pillsbury Potato Total	Pillsbury Potato Fecal	State Mill Total	State Mill Fecal	Frito Lay Total	Frito Lay Fecal
	-	-	-	-	16,000,000	5,400,000	3,300,000	230,000	< 200	< 200	7,900,000	490,000		
	5,400,000	3,500,000	2,200	< 200	13,000,000	4,900,000	9,200,000	1,300,000	13,000	4,900	4,900,000	1,300,000		
	1,300,000	790,000	3,100	80	13,000,000	1,300,000	>160,000,000	160,000,000	< 2,000	< 2,000	3,480,000	500,000		
	3,300,000	1,100,000	10,900	490	3,300,000	790,000	4,600,000	200,000	20	< 20	490,000	220,000		
	490,000	31,000	10,900	330	1,700,000	170,000								
	460,000	330,000	17,200	460	24,000,000	2,200,000	172,000,000	330,000	< 20	< 20	27,500,000	1,300,000		
	-	-	22,100	1,300	24,000,000	2,800,000	49,000,000	1,410,000	< 20	< 20	1,300,000	540,000		
	170,000	80,000	22,100	2,300	7,900,000	700,000	79,000,000	790,000	> 160,000	> 160,000	1,300,000	130,000	740,000	< 2,000
	20,000	< 20,000	92,000	2,120	3,300,000	460,000	27,800,000	170,000	> 160,000	> 160,000	7,900,000	1,300,000	230,000	2,000
	1,700,000	1,300,000	22,100	1,720	490,000	490,000	13,000,000	1,720,000	< 20	< 20	2,400,000	330,000	1,300,000	7,900
	790,000	790,000	22,100	1,720			346,000,000	330,000	< 20	< 20	9,200,000	790,000	330,000	800
	3,500,000	3,500,000	24,000	2,300	2,200,000	1,300,000	221,000,000	330,000	33,000	6,000	13,000,000	330,000	490,000	17,500
	1,700,000	1,700,000	4,000	1,300	7,000,000	4,900,000	130,000,000	200,000	2,200	1,720	3,300,000	230,000	130,000	200
	5,400,000	5,400,000	17,200	490	13,000,000	490,000	240,000,000	130,000	< 20	< 20	4,900,000	790,000	172,000	500
	-	-	10,900	1,300	> 160,000,000	>160,000,000	70,000,000	330,000	20	< 20	34,000,000	130,000	172,000	200
					7,900,000	790,000								
MEAN	940,000	797,000			6,360,000	1,400,000	56,300,000	609,000			4,840,000	534,000		

Table 2-B

Summary of Industrial Waste Samples

Red River of the North

	Flow (MGD) Flume	Temp. °C. Flume	Flow (MGD) Process	Temp. °C. Process	[illegible] mg/l	pH		Suspended Solids Determination				5-day 20°C. BOD			
								Flume		Process		mg/l		lbs/day	
						Flume	Process	Total	Volatile	Total	Volatile	Flume	Process	Flume	Process
	Pillsbury Potato Flour														
	.46	10	-	20	7.8	7.9	11.7	618	222	4050	3480	74.8	1860	286	4500
	.50	12	.29	24		4.8	12.2	302	83	4580	3910	34.2	3180	142	7700
	.50	10	.29	23		8.1	12.3	444	122	5810	5130	49.3	4600	205	11300
	.50	11	-	23		7.7	11.7	639	165	7040*	5520*	62.5	1410	261	3410*
Avg.	.49	10.5	.29	22.5	8.4	7.1	11.9	501	148	4840	4130	55.2	2783	223	7833

* Treated

Table 2-C

Summary of Industrial Waste Samples

Red River of the North

	Flow (MGD)	Temp. °C.	Suspended Solids Total	Suspended Solids Volatile	pH	5-day 20°C BOD lbs/day	
Rogers Brothers Potato Company						ppm	#/day
	.20	19	10,800	3,060	6.7	4770	7950
	.31	22	11,200	7,180	7.8	6240	16100
	.17	20	492	255	5.3	1620	2300
Avg.	.23	20	7,497	3,498	6.6	4210	8783

Table 3-A

Bottom Organism Data
Number of Kinds and Number per Square Foot
Red River of the North
September 1964

River Mile	Red River of the North																			
	536 RR-4		501 RR-5		483 RR-6		472 RR-7		462 RR-9		441 RR-10		436 RR-11		426 RR-12		416 RR-14		403 RR-15	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*
Mayflies																				
Sprawlers	5	15	4	19	2	*	2	*	2	*	1	*	1	*	2	*	2	*	4	10
Burrowers	1	41	1	5	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-
Caddisflies	2	*	2	14	1	*	1	*	1	*	-	-	-	-	2	*	1	126	1	20
Riffle Beetles	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-
Black Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	1	*	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	1	*	-	-	-	-	-	-	-	-
Clams	1	*	-	-	1	2	-	-	-	-	-	-	1	8	-	-	-	-	-	-
Midges	1	3	-	-	1	*	1	*	-	-	-	-	-	-	-	-	-	-	1	*
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	-	-	-	-	-	-	-	-	-	-	1	8	1	*	-	-	-	-	-	-
Leeches	1	2	-	-	-	-	-	-	-	-	1	*	1	*	1	*	1	3	1	2
Horsehair Worms	-	-	-	-	-	-	-	-	1	*	-	-	-	-	-	-	1	*	-	-
Sludgeworms	1	3	-	-	1	*	1	*	1	4	1	32	-	-	1	8	1	2	-	-
Total	14	69	7	38	6	-	5	-	7	11	5	43	4	11	6	10	8	137	8	34

*Collected in qualitative sample, counted as 1 in total.

Table 3-A (Cont'd.)

Bottom Organism Data
Number of Kinds and Number Per Square Foot
Red River of the North
September 1964

River Mile	Red River of the North																			
	386 RR-16		375 RR-18		357 RR-19		347 RR-20		335 RR-21		319 RR-22		305 RR-23		298 RR-27		292 RR-28		286 RR-29	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	1	*	1	*	2	4	1	*	1	3	2	*	-	-	1	*	1	*	-	-
Mayflies																				
Sprawlers	4	*	3	4	2	3	-	-	2	6	3	*	2	*	3	10	2	*	3	*
Burrowers	1	*	-	-	3	27	2	7	1	2	-	-	1	2	2	10	2	2	-	-
Caddisflies	1	3	1	2	1	2	2	*	-	-	-	-	-	-	1	*	1	*	-	-
Riffle Beetles	-	-	-	-	-	-	1	7	-	-	1	*	-	-	-	-	1	*	1	*
Black Flies	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	1	*	1	*	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	1	*	1	*	1	*	1	*	-	-	-	-	1	2	-	-	-	-
Midges	-	-	1	*	1	*	1	3	-	-	-	-	-	-	-	-	-	-	1	8
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-
Leeches	-	-	1	*	1	*	-	-	-	-	-	-	-	-	-	-	1	*	1	*
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	5	1	5	1	5	1	3	1	2	1	3	1	*	1	2	1	5	1	12
Total	9	16	9	15	12	44	9	23	6	14	8	10	5	-	10	28	10	14	7	25

*Collected in qualitative sample, counted as 1 in total.

Table 3-A (Cont'd)

Bottom Organism Data
Number of Kinds and Number Per Square Foot
Red River of the North
September 1964

River Mile	Red River of the North														Sheyenne		Wild Rice, Minn.		Red Lake River	
	279 RR-30		274 RR-31		254 RR-32		236 RR-34		208 RR-36		176 RR-37		158 RR-39		1 SH-13		3 WR-7		68 RL-24	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	-	-	-	-	1	*	-	-	-	-	-	-	-	-	1	*	2	*
Mayflies																				
Sprawlers	4	*	3	*	4	*	1	*	3	*	5	8	2	*	1	5	3	*	2	*
Burrowers	-	-	-	-							1	24	1	5					3	7
Caddisflies	1	*	1	*	1	*	-	-	-	-	2	5	-	-	2	14	2	*	-	-
Riffle Beetles	-	-	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	1	*	1	*	-	-	-	-	-	-	-	-	-	-
Midges	1	4	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	1	*
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-	-	-	1	*
Bloodworms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leeches	-	-	1	8	-	-	-	-	-	-	-	-	-	-	1	8	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	1	4	-	-	-	-	-	-	1	8	-	-
Sludgeworms	1	4	1	8	1	8	-	-	1	8	-	-	1	5	-	-	1	4	-	-
Total	7	13	7	19	6	13	3	3	6	16	8	37	5	13	6	31	9	18	10	14

*Collected in qualitative sample, counted as 1 in total.

Table 3-A (Cont'd.)

Bottom Organism Data
Number of Kinds and Number Per Square Foot
Red River of the North
September 1964

River Mile	Red Lakes River				Forest		Park		Pembina		Otter Tail River								Bois De Sioux		Wild Rice, N.D.	
	28		0.2		7		5		0.5		59		42		20		2		9		8	
	RL-25		RL-26		FR-33		PR-35		PE-38		OT-40		OT-41		OT-2		OT-3		BD-1		WD-8	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	1	*	2	*	-	-	1	*	-	-	-	-	1	*	-	-	1	*	-	-	-	-
Mayflies																						
Sprawlers	1	*	3	*			1	*	1	*	2	27	1	*	3	*	4	16	1	2	-	-
Burrowers	3	76					2	*	1	*			1	*	2	42			2	6	-	-
Caddisflies	1	*	-	-	-	-	1	*	2	*	-	-	2	*	3	7	3	33	-	-	-	-
Riffle Beetles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
Black Flies	-	-	-	-	-	-	-	-	1	*	-	-	-	-	-	-	-	-	-	-	-	-
Alder Flies	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	1	4	1	*	-	-	1	*	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-	-	-	1	*	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-
Clams	-	-	-	-	-	-	1	*	-	-	1	*	-	-	-	-	-	-	-	-	-	-
Midges	-	-	-	-	-	-	1	76	1	*	-	-	-	-	1	2	-	-	-	-	-	-
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	-	-	-	-	1	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leeches	-	-	-	-	1	4	-	-	-	-	1	*	-	-	-	-	-	-	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	*	1	4	1	24	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
Total	7	81	6	9	4	40	8	83	6	6	5	30	6	6	9	54	10	54	5	10	-	-

*Collected in qualitative sample, counted as 1 in total.

Table 3-B

Bottom Organism and Algal Data
Number of Kinds and Number Per Square Foot
Red River of the North
November 1964

	Red River of the North																			
River Mile	536 RR-4		501 RR-5		483 RR-6		472 RR-7		462 RR-9		441 RR-10		436 RR-11		426 RR-12		416 RR-14		403 RR-15	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mayflies																				
Sprawlers	2	*	2	*	2	*	1	*	1	*	-	-	-	-	-	-	1	*	1	*
Burrowers	-	-	-	-	-	-	-	-	1	*	-	-	-	-	-	-	-	-	-	-
Caddisflies	2	*	2	*	-	-	1	*	1	*	-	-	-	-	-	-	1	605	1	*
Riffle Beetles	-	-	-	-	-	-	1	*	1	4	-	-	-	-	-	-	-	-	-	-
Black Flies	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	1	7
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges	1	*	1	*	1	*	1	*	-	-	-	-	1	12	1	216	1	7	1	4
Sewage Flies	-	-	-	-	-	-	-	-	-	-	1	12	1	4	-	-	-	-	-	-
Bloodworms	-	-	-	-	-	-	-	-	1	8	1	4	1	96	1	156	1	7	1	14
Leeches	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	20	1	20
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	-	-	-	-	1	*	-	-	1	4	1	12	1	80	1	1116	1	218	1	598
Total	6	-	6	-	4	-	4	-	6	19	3	26	4	192	4	1492	6	858	7	645
Algae No./ml									2500		4700		8200		7100				7000	

*Collected in qualitative sample, counted as 1 in total.

Table 3-B (Cont'd.)

Bottom Organism and Algal Data
Number of Kinds and Number Per Square Foot
Red River of the North
November 1964

River Mile	Red River of the North																			
	386		375		357		347		335		319		305		298		292		286	
	RR-16		RR-18		RR-19		RR-20		RR-21		RR-22		RR-23		RR-27		RR-28		RR-29	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	-	-	1	2	1	5	1	10	-	-	-	-	-	-	-	-	-	-
Mayflies																				
Sprawlers	1	2	1	51	2	27	2	15	-	-	1	*	3	34	2	*	-	-	-	-
Burrowers	1	7	1	153	1	14	1	14	1	20	1	8	-	-	-	-	-	-	-	-
Caddisflies	2	2	1	255	1	340	1	2	-	-	-	-	-	-	-	-	-	-	-	-
Riffle Beetles	1	2	-	-	1	75	1	5	1	20	-	-	-	-	-	-	-	-	-	-
Black Flies	-	-	-	-	-	-	1	*	-	-	-	-	-	-	-	-	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	-	-	-	-	-	-	1	12	-	-	-	-	-	-
Midges	1	68	1	183	1	353	1	543	1	68	1	11	1	81	1	10	-	-	-	-
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	-	-	1	41	1	14	1	76	1	*	1	5	1	7	1	7	-	-	-	-
Leeches	1	3	1	2	-	-	1	2	-	-	-	-	-	-	1	2	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	75	1	97	1	27	1	87	1	31	1	72	1	12	1	265	-	-	1	28
Total	8	159	7	782	9	852	11	750	6	150	5	97	7	146	6	285	0	0	1	28

*Collected in qualitative sample, counted as 1 in total.

Algae No. /ml	9100	10900	19100	20950	27500	26700	35650	22050	14700	20750

Table 3-B (Cont'd.)

Bottom Organism and Algal Data
Number of Kinds and Number Per Square Foot
Red River of the North
November 1964

	Red River of the North														Sheyenne		Wild Rice, Minn.		Red Lakes River	
River Mile	279		274		254		236		208		176		158		1		3		66	
	RR-30		RR-31		RR-32		RR-34		RR-36		RR-37		RR-39		SH-13		WM-17		RL-24	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*
Mayflies																				
Sprawlers	-	-	2	12	1	*	1	4	1	*	1	4	3	*	1	65	3	*	1	*
Burrowers	-	-			1	16			1	*	1	*	1	8			1	8		
Caddisflies	-	-	-	-	1	*	1	*	-	-	-	-	-	-	1	333	2	*	1	20
Riffle Beetles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	1	10
Black Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	48	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges	1	4	1	52	1	12	1	4	1	12	1	4	-	-	1	19	1	4	1	27
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	1	4	-	-	1	4	1	4	1	4	-	-	-	-	-	-	-	-	-	-
Leeches	-	-	1	4	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	20	1	608	1	192	1	88	1	108	1	8	1	124	1	8	1	52	1	14
Total	3	28	5	676	7	230	5	101	5	126	4	17	5	133	7	476	8	66	6	73

*Collected in qualitative sample, counted as 1 in total.

Algae No./ml	18400	18400	14400	24250	27100		15000			

Table 3-B (Cont'd.)

Bottom Organism and Algal Data
Number of Kinds and Number Per Square Foot
Red River of the North
November 1964

River Mile	Red Lakes River				Forest		Park		Pembina		Otter Tail River				Bois De Sioux		Wild Rice, N.D.	
	28		0.2		7		5		0.5		20		2		9		2	
	RL-25		RL-26		FR-33		FR-35		PE-38		OT-2		OT-3		BD-1		WD-2	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mayflies																		
Sprawlers									2	*	2	*					2	*
Burrowers			1	8							1	*			1	*		
Caddisflies	-	-	-	-	-	-	-	-	1	34	2	*	1	*	-	-	2	*
Riffle Beetles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Flies	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges	1	8	1	4	1	8	1	392	1	82	-	-	1	*	1	*	1	*
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	-	-	1	68	-	-	-	-	-	-	1	*	-	-	-	-	-	-
Leeches	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	28	1	92	1	68	1	32	1	14	-	-	-	-	-	-	-	-
Total	2	36	4	164	2	76	2	424	5	131	7	-	3	-	4	-	5	-

*Collected in qualitative sample, counted as 1 in total.

Algae No./ml 6550

Table 3-C

Bottom Organism Data
Number of Kinds and Number Per Square Foot
Red River of the North
January 1965

River Mile	Red River of the North															
	462 RR-9		441 RR-10		436 RR-11		426 RR-12		416 RR-14		403 RR-15		386 RR-16		375 RR-18	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mayflies																
Sprawlers	1	*	-	-	-	-	-	-	-	-	1	*	1	2	2	5
Burrowers	1	4	-	-	-	-	-	-	-	-	1	8			1	8
Caddisflies	1	*	-	-	-	-	-	-	2	240	2	32	2	15	2	173
Riffle Beetles	-	-	-	-	-	-	-	-	1	14	1	*	-	-	-	-
Black Flies	-	-	-	-	-	-	-	-	1	7	-	-	1	*	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	32
Clams	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges	1	24	-	-	-	-	1	72	1	88	1	401	1	48	1	92
Sewage Flies	-	-	1	*	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	-	-	-	-	-	-	1	64	-	-	1	3	-	-	-	-
Leeches	-	-	1	8	-	-	1	8	-	-	-	-	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	24	1	264	1	44	1	354	1	39	1	109	1	15	1	25
Total	5	54	3	273	1	44	4	498	6	388	8	555	6	81	9	340

*Collected in qualitative sample, counted as 1 in total.

Algae No./ml			570		850				1200		625		450		850	

Table 3-C (Cont'd.)

Bottom Organism Data
Number of Kinds and Number Per Square Foot
Red River of the North
January 1965

River Mile	Red River of the North															
	357 RR-19		347 RR-20		335 RR-21		319 RR-22		305 RR-23		298 RR-27		279 RR-30		274 RR-31	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	1	*	-	-	-	-	-	-	-	-	-	-	-	-
Mayflies																
Sprawlers	2	5	1	2												
Burrowers	2	5	2	36	2	66	1	*			1	20				
Caddisflies	1	88	-	-	-	-	-	-	-	-	2	15	-	-	-	-
Riffle Beetles	1	41	1	20	1	12	-	-	-	-	1	2	-	-	-	-
Black Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges	1	212	1	569	1	398	1	53	-	-	1	83	1	44	1	71
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	1	3	1	148	1	7	1	49	1	100	-	-	-	-	-	-
Leeches	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	22	1	83	1	48	1	27	-	-	1	2	-	-	1	10
Total	10	378	8	859	6	531	4	130	1	100	6	122	1	44	2	81

*Collected in qualitative sample, counted as 1 in total.

Algae No./ml	310	360	360	420	700		620	520

Table 3-C(Cont'd.)

Bottom Organism Data
Number of Kinds and Number Per Square Foot
Red River of the North
January 1965

River Mile	Red River of the North						Sheyenne		Wild Rice, Minn.		Red Lakes River					
	254		236				1		3		66		28		0.2	
	RR-32		RR-34		RR-36		SH-13		WH-17		RL-24		RL-25		RL-26	
	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.	No. Kinds	No. Sq. ft.
Stoneflies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mayflies																
Sprawlers	1	*	1	*	1	*			1	4	1	5				
Burrowers	1	4	1	*	1	2			1	4						
Caddisflies	1	*	-	-	1	20	1	5	-	-	3	31	-	-	-	-
Riffle Beetles	-	-	-	-	1	3	1	5	-	-	1	2	-	-	-	-
Black Flies	-	-	-	-	-	-	-	-	1	*	-	-	-	-	-	-
Alder Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clams	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges	1	68	1	4	1	250	1	18	-	460	1	229	1	8	1	24
Sewage Flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bloodworms	1	4	-	-	-	-	-	-	-	-	-	-	1	8	-	-
Leeches	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horsehair Worms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sludgeworms	1	16	1	28	-	-	1	20	1	260	1	2	1	22	1	44
Total	6	94	4	34	5	276	4	48	4	729	7	269	3	38	2	68

*Collected in qualitative sample, counted as 1 in table.

Algae No./ml			830		310		990		150							

APPENDIX II

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TECHNICAL APPENDIX

INTRODUCTION

The capacity of a stream to assimilate pollution is a function of several interrelated factors involving hydrology, biological satisfaction, natural purification, and stream biota. If each factor can be reasonably defined and its importance in the stream balance shown, it should, theoretically, be possible to vary these conditions and note the effect on the dependent measure of water quality, whether it be dissolved oxygen or bacteriological indicator organisms. It is the purpose of this appendix to review the principles of self-purification with reference to organic wastes and to demonstrate the application of these principles to the determination of the pollutional capacity of streams.

HYDROLOGY

Expected River Flows

The U. S. Geological Survey maintains several recording gages in the Red River of the North study area. Those selected for analysis for this report are at Fargo, North Dakota, Crookston, Minnesota, and Grand Forks, North Dakota. From statistical relationships established between river flow and probability of occurrence, the mean expected discharge as well as the discharge below which values will occur once in ten years on a mean monthly basis were determined. These values are summarized in Table A-1.

Time of Travel

The reactions of unstable pollutional materials are functions of time. The satisfaction of B.O.D. and the dieoff of coliform bacteria proceed systematically with time of travel downstream from a source of waste. To describe the affected area over which pollution is occurring and to calculate effects based on the time of travel, cross sections of the river were obtained at every bridge within the study area during the September phase of the survey. These data, together with the river discharge data obtained from the U. S. Geological Survey, enabled the velocity between sampling stations to be calculated and estimates of time of travel to be made.

Table A-1

Most Probable Values of Stated Stream Flows in cfs

Red River of the North and Red Lake River

Month	Mean Monthly	10-yr. Monthly Low Flow
Fargo, North Dakota		
January	203	80
February	203	100
March	380	210
April	880	340
May	760	325
June	930	205
July	740	210
August	330	90
September	240	65
October	200	63
November	190	68
December	180	75
Crookston, Minn.		
January	305	82
February	285	88
March	495	175
April	2600	640
May	1400	550
June	1220	420

Table A-1 (Cont.)
Most Probable Values of Stated Stream Flows in cfs
Red River of the North and Red Lake River

Month	Mean Monthly	10-yr. Monthly Low Flow
Crookston, Minn. (Cont.)		
July	720	240
August	380	93
September	480	112
October	430	128
November	390	125
December	335	68
Grand Forks, North Dakota		
January	540	185
February	530	220
March	1050	340
April	6200	2000
May	3350	1500
June	3400	1050
July	2100	550
August	970	250
September	920	265
October	790	280
November	710	265
December	610	205

Examination of the rating curves of several U.S.G.S. gaging stations showed a mathematically definable relationship between river discharge (Q) and velocity (V). In the range of flows, covered by the rating curves, river discharge is a function of velocity in the form:

$$Q_1 = Q_0 \left[1 + 10^{k(V_1 - V_0)} \right] \qquad (1)$$

where:

Q_1 = discharge in cfs at velocity V_1 in fps

Q_0 = discharge in cfs at velocity V_0 in fps

k = constant rate at which Q is changing with V

Solution of this equation for the gaging stations at Fargo, North Dakota, Halstad, Minnesota and Grand Forks, North Dakota showed k values of .856/fps, .893/fps and .834/fps respectively, with a mean of .861/fps. Assuming this relationship to hold for the entire river system, the velocity occurring at any given discharge may be calculated using the observed river discharge and velocity at a given sampling station from the September survey. The accuracy of these estimates was demonstrated by the discharge of clean-up wastes from the American Crystal Sugar Company plant at Moorhead in January. This waste, with a B.O.D. value much higher than the two municipal treatment plant effluent traveled downstream as a slug and its movement was traced. From the outfall of the beet sugar plant to a point in the Red River near Climax, Minnesota, the observed time of travel of this slug was 8.0 days. The calculated estimate was 8.3 days.

The estimated times of travel for the three phases of this study are listed in Table A-2.

Table A-2

Estimated Times of Travel

Red River of the North & Red Lake River

Station	River Mile	Time of Travel (Days)		
		Sept.	Nov.	Jan.
Fargo-Moorhead to Grand Forks				
Fargo-Moorhead	448	0	0	0
RR-10	441	0.3	0.2	0.3
RR-11	436	0.5	0.4	0.4
RR-12	426	1.0	0.8	0.8
RR-14	416	1.6	1.2	1.3
RR-15	403	2.5	1.9	2.0
RR-16	386	4.2	3.0	3.3
RR-18	375	5.2	3.8	4.1
RR-19	357	7.3	5.3	6.0
RR-20	347	8.9	6.3	7.2
RR-21	335	10.1	7.3	8.3
RR-22	319	12.8	8.5	9.8
RR-23	305	18.3	10.7	12.3
RR-27	298	22.0	13.7	17.0
Grand Forks to International Boundary				
G.F. - E.G.F.	296	0	0	0
RR-28	292	0.8	0.3	0.4
RR-29	286	1.4	0.7	1.0
RR-30	279	2.3	1.2	1.7
RR-31	274	2.9	1.6	2.2
RR-32	254	5.1	2.9	4.1
RR-34	236	7.1	4.0	5.6
RR-36	208	9.5	5.6	7.7
RR-37	176	12.0	7.5	10.3
RR-39	158	14.2	8.8	12.1

Table A-2

Estimated Times of Travel

Red River of the North & Red Lake River

Station	River Mile	Time of Travel (Days)		
		Sept.	Nov.	Jan.
Crookston to Grand Forks (Red Lake River)				
Crookston	51	0	0	
RL-43	49		0.1	
RL-25	28	1.8	0.7	
RL-42	14	3.3	1.2	
RL-26	0	6.7	2.3	

WASTE ASSIMILATION

Many waste substances are chemically or biologically unstable and their rates of decrease can be predicted or measured directly. The concentration of dissolved oxygen, however, depends not only on the rate of oxidation of decaying organic matter but also on the rate of reaeration of the stream. The simultaneous action of deoxygenation and reaeration produces a pattern in the dissolved oxygen concentration along the stream known as the dissolved oxygen sag curve. This concentration pattern can be mathematically approximated by the differential equation

$$\frac{dD}{dt} = k_r L - k_2 D \qquad (2)$$

where:
L = concentration of organic matter (B.O.D.)
k_r = rate of oxidation of organic matter
D = dissolved oxygen deficit from a saturated value
k_2 = rate of reaeration
$\frac{dD}{dt}$ = change of deficit with time

This equation states that the rate of change of dissolved oxygen in a stream is a function of two independent rates proceeding at the same time. The dissolved oxygen tends to be decreased by its use in the satisfaction of decaying organic matter and to be increased by reaeration from the atmosphere, which is a function of the hydraulic factors of the stream. Integration of equation (2) gives:

$$D_t = \frac{k_r L_o}{k_2 - k_r} \left(10^{-k_r t} - 10^{-k_2 t}\right) + D_o \left(10^{-k_2 t}\right) \qquad (3)$$

where: D_t = dissolved oxygen deficit at time t.

k_r = rate of oxidation of organic matter in the stream.

L_o = concentration of organic material (B.O.D.) in the stream just below the waste discharge.

t = time of travel in the stream.

Other factors such as photosynthesis, second stage B.O.D. demand or oxygen demand from bottom deposits may be incorporated into the original differential equation. The subsequent integration will yield an equation similar in form to equation (3), but with the inclusion of the effect of these additional variables upon the resulting dissolved oxygen deficit. This procedure was necessary in certain portions of the Red River and the results will be discussed in the evaluation of data from these areas.

The biochemical oxygen demand of a waste exerted in any interval of time is expressed by the equation:

$$Y_T = L_o \left(1 - 10^{-k_1 t}\right) \qquad (4)$$

where: Y_T = B.O.D. exerted at time t.

k_1 = rate of deoxygenation in a laboratory bottle.

L_o = ultimate or total amount of organic material available for oxidation.

The 5-day B.O.D. (Y_5) which is commonly reported is a measure of an indication of the total amount of B.O.D. available. Since it is this total amount of material that is depleting the oxygen resources of the stream, its value is necessary in the solution of the sag equation (Equation 3). This predicates a knowledge of the laboratory deoxygenation rate, k_1, for each sampling point through which the sag is to be calculated. There are methods available for a determination of this k_1 rate and these have been used in evaluating the B.O.D. data obtained in this survey. Consequently, the total quantity of B.O.D. available in the stream at each point of interest has been calculated. The rate of removal of B.O.D. in the stream (k_r) is given by

$$k_r = \frac{\text{LOG } L_{o_1} - \text{LOG } L_{1_2}}{t} \qquad (5)$$

where: L_{o_1} = ultimate B.O.D. at the upstream station in the reach.

L_{o_2} = ultimate B.O.D. at the downstream station in the reach.

t = time of travel through the reach.

The initial dissolved oxygen deficit (D.O.) may be determined from observed data. The reaeration coefficient (k_2) has been defined by several researchers as a function of velocity and depth. These measurable physical factors were obtained by cross sections at each station and representative values of k_2 through the reaches of interest were established.

The temperature influence of the deoxygenation and reaeration coefficients may be expressed as follows:

$$k_{T_2} = k_{T_1} \; \theta^{T_2 - T_1} \qquad (6)$$

where: k_{T_2} is the rate at temperature T_2

k_{T_1} is the rate at temperature T_1

For the deoxygenation rate, θ is equal to 1.047, and for the reaeration rate, θ has a value of 1.024.

The critical point of the dissolved oxygen sag equation is the minimum dissolved oxygen concentration or maximum deficit for a given waste loading. At this critical point the reaeration function exactly equals the deoxygenation function and the change of dissolved oxygen with respect to time is equal to zero from equation (2). Therefore, at this point:

$$k_r L = k_2 D$$

Expressing L in terms of waste input at the discharge point, the equation becomes

$$k_r L_o \left(10^{-k_r t_c}\right) = k_2 D \qquad (7)$$

where t_c is the time of travel to the critical point.

The time, t_c, is

$$t_c = \frac{1}{k_2 - k_r} \; \mathrm{LOG} \left[\frac{k_2}{k_r} \left(1 - \frac{D_o(k_2 - k_r)}{k_r L_o}\right) \right] \qquad (8)$$

Therefore, the waste load, L_o, which may be discharged to maintain values of dissolved oxygen greater than or equal to an allowable minimum, may be calculated from Equations (7) and (8). Likewise, the value of dissolved oxygen which would result from a given waste discharge may also be calculated.

B.O.D. VALUES

To determine the ultimate first stage demand (L_o) at a particular station, it is necessary to know the rate at which satisfaction of organic material is taking place. This can not be obtained from the 5-day B.O.D. alone. If the classical first order reaction (Equation 4) is used, an additional 2-day B.O.D. permits solution for the k_1 rate by simultaneous equations as follows:

$$Y_2 = L_o (1 - 10^{-2k_1})$$

$$Y_5 = L_o (1 - 10^{-5k_1})$$

With the k_1 rate known, it becomes a simple matter to solve for the ultimate demand (L_o) by using the average 5-day B.O.D. at that sampling location. Two-day B.O.D.'s were collected on 20 percent of the samples at each station in November, 1964.

Daily B.O.D.'s were performed for twenty days at selected river stations and on the effluents from the Fargo municipal plant, the Moorhead sugar plant, and the Pillsbury potato plant at Grand Forks. These long-term B.O.D.'s were done to give a clearer picture of the actual rate of satisfaction and to illustrate any second stage demand.

Since river temperatures in November were near 5°C., the effect of the colder water will exert an inhibiting action on the rate of satisfaction of B.O.D. The commonly accepted temperature correction for k_1 rates is Equation 6 with Θ equal to 1.047. There has been some questioning of the use of this factor to project to extremely cold temperatures, since it is believed that at 5° and below, psycrophilic or cold-loving bacteria become ascendant and supersede the mesophilic or intermediate temperature bacteria which had been accomplishing the degradation of the organic material. To test this hypothesis, simultaneous 2-day and 5-day B.O.D.'s were set up at 5°C. to compare with the 2-day and 5-day B.O.D.'s at 20°C. The value of θ was then obtained from a knowledge of the respective k_1 rates. These values and the 20°C. k_1 rates as well as the rates from the long-term B.O.D.'s at 20°C. are shown in Table A-3. Although the results are quite varied and show a wide range, when plotted as a normal probability distribution the mean θ is 1.047. The normal distribution plot is shown in Chart A-1.

Table A-3

Deoxygenation Rates (k_1)

Red River of the North & Red Lake River

Station	River Mile	k_1 Long Term 20°C.	k_1 20°	k_1 5°	θ
Red River of the North					
RR- 9	462	.10	.11	.01	1.149
RR-10	441	.20	.13	.25	.663
RR-11	436		.10	.24	.569
RR-12	426		.10	.04	1.065
RR-14	416		.08	.07	1.011
RR-15	403		.08	.11	.795
RR-16	386		.04	.09	.629
RR-18	375		.03	.03	1.029
RR-19	357	.06	.07	.08	.888
RR-20	347		.09	.02	1.106
RR-21	335		.11	.06	1.039
RR-22	319		.10	.01	1.169
RR-23	305	.09	.09	.02	1.098
RR-27	298		.10	.05	1.038
RR-28	292	.13	.12	.06	1.048
RR-29	286		.14	.03	1.106
RR-30	279		.12	.03	1.111
RR-31	274	.13	.10	.04	1.062
RR-32	254		.12	.02	1.113
RR-34	236		.12	.07	1.040
RR-36	208	.08	.12	.10	1.008
RR-37	176		.06	.07	.960
RR-39	158		.08	.08	.983

Table A-3 (Cont.)

Deoxygenation Rates (k_1)

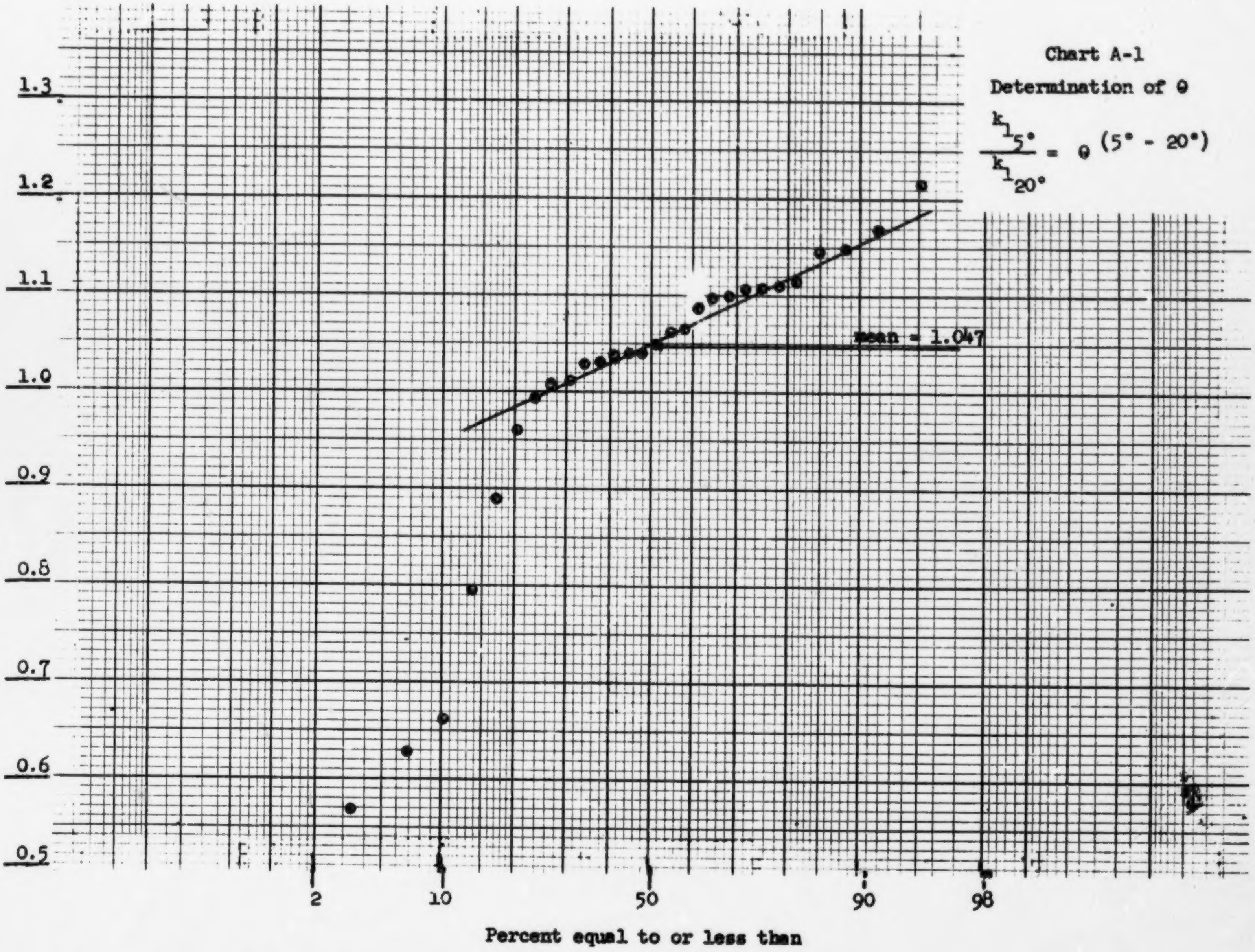
Red River of the North & Red Lake River

Station	River Mile	k_1 Long Term 20°C.	k_1 20°	k_1 5°	θ
Red Lake River					
RL-24	298-66		.07	.02	1.095
RL-43	298-46		.14	.02	1.146
RL-25	298-28		.14	.09	1.031
RL-42	298-14		.14	.04	1.087
RL-26	298-0	.08	.09	.01	1.214

Chart A-1

Determination of θ

$$\frac{k_{1_{5^\circ}}}{k_{1_{20^\circ}}} = \theta\,(5^\circ - 20^\circ)$$



EVALUATION OF DATA

Red River of the North - Fargo to Grand Forks

When the American Crystal Sugar Company plant at Moorhead was discharging wastes, the B.O.D. in the river below Fargo-Moorhead exhibited an extremely rapid rate of decomposition. The B.O.D. remaining at Georgetown, Minnesota, 1.2 days time of travel downstream from the plant outfall, was about 27 percent of that observed below the outfall. Two factors account for this observation. The waste discharged by the American Crystal Sugar Company plant contained sugar, a readily oxidizable carbonaceous material. In addition, large slime-like growths, principally Sphaerotilus natans were observed in the stream through Georgetown. Sphaerotilus natans is a filamentous material which requires carbon for growth and readily absorbs carbonaceous organic matter for use as food. This slime growth was not prevalent during the September phase of the survey. In September, the carbonaceous material discharged from the municipal plants was about one-fifth the quantity in November, and this material was not in an easily oxidizable form, having been subjected to secondary treatment. The respiration of the slime growths in absorbing the B.O.D. was measured by means of light and dark bottles suspended in the stream in the same manner as that used to measure the production of oxygen by algae.

Also, when the sugar plant was discharging, large amounts of organic bottom deposits were observed in the stream bed from the waste outfalls to below the confluence with the Sheyenne River. These bottom deposits also exerted a significant oxygen demand.

Both the respiration of the slime growths and the effect of bottom demand were considered constant with time and were added to the basic differential equation (2)

$$\frac{dD}{dt} = k_r L - k_2 D + R_s + B \qquad (9)$$

where R_s = net respiration of the slimes

B = benthal or bottom demand

This differential equation integrates to:

$$(10) \qquad D_t = \frac{k_r L_o}{k_2 - k_r} \left(10^{-k_r t} - 10^{-k_2 t}\right) + \frac{R_s}{k_2}\left(1 - 10^{-k_2 t}\right) + \frac{B}{k_2}\left(1 - 10^{-k_2 t}\right) + D_o\left(10^{-k_2 t}\right)$$

Chart A-2 shows the ultimate B.O.D. values in pounds per day in the river versus time of travel in this stretch during November. The profile was constructed only from the waste sources to Georgetown, Minnesota, since at Georgetown the D.O. had recovered to a level greater than 5.0 mg/l. All waste sources were considered to be discharged at one point, river mile 448. The sharp increase in B.O.D. at 0.7 days is due to the residual B.O.D. in the Sheyenne River at the confluence of the two streams. The excessive rate of deoxygenation of the wastes in the river, plus the added demand from bottom deposits, combine to cause a rapid depletion of the dissolved oxygen. A D.O. profile was calculated from below the sources of waste to Perley, Minnesota, as is shown in Chart A-3. The values used in this calculation are summarized in Table A-4. Chart A-3 shows a minimum D.O. value of 1.5 mg/l to occur just before the confluence with the Sheyenne River.

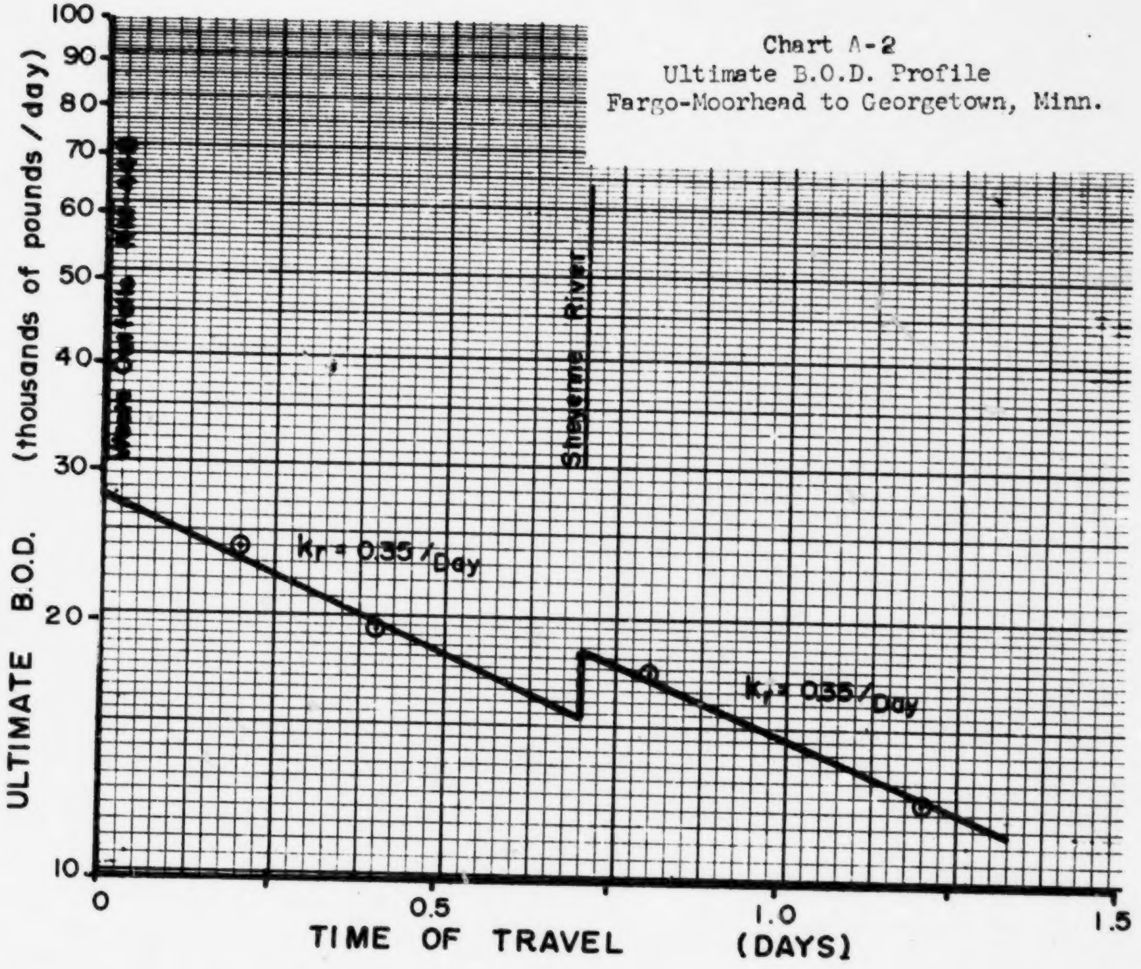


Chart A-2
Ultimate B.O.D. Profile
Fargo-Moorhead to Georgetown, Minn.

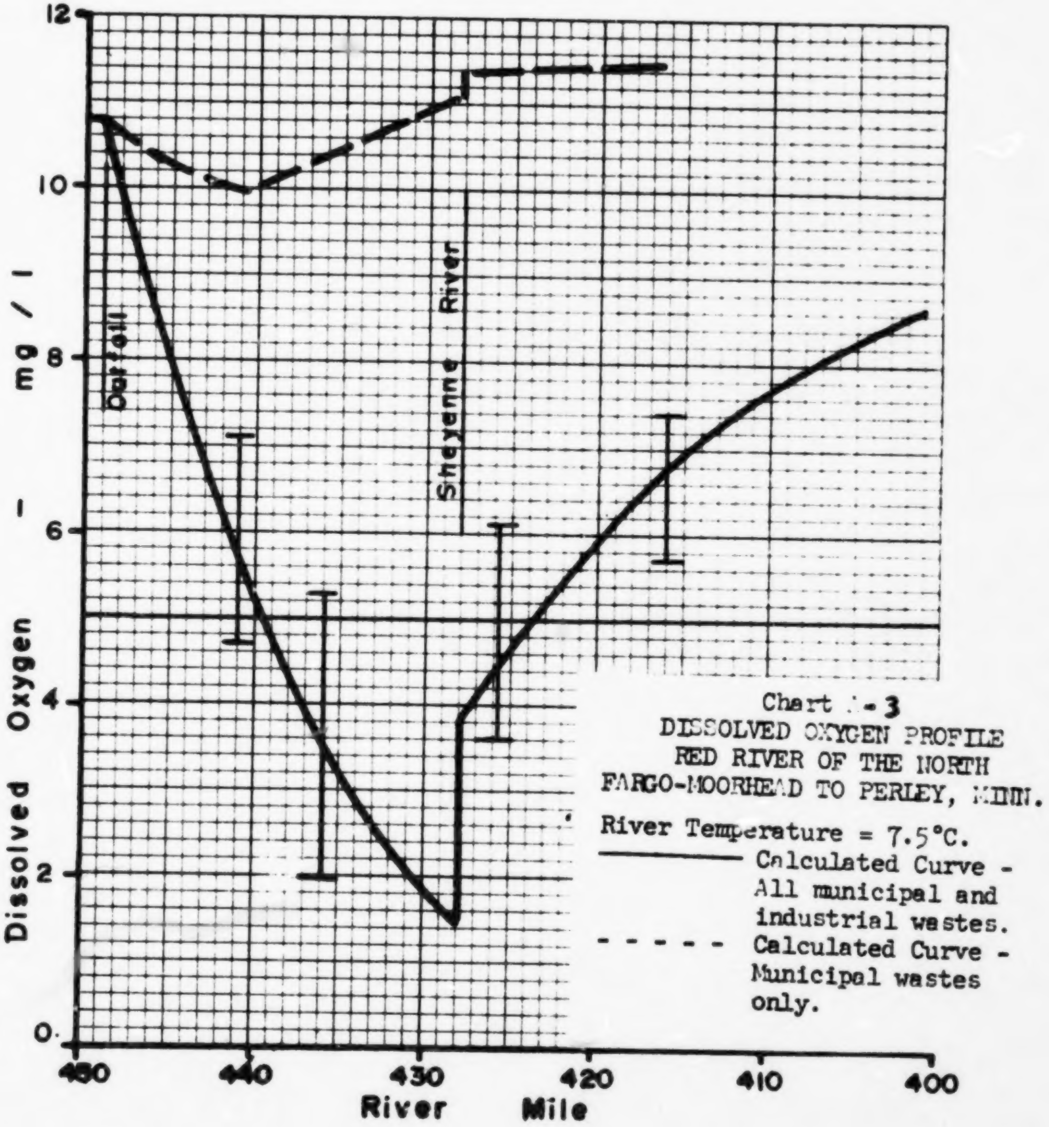


Chart [illegible]-3
DISSOLVED OXYGEN PROFILE
RED RIVER OF THE NORTH
FARGO-MOORHEAD TO PERLEY, MINN.

River Temperature = 7.5°C.

Table A-4

Values Used in Calculation of D.O. Profiles

Red River of the North - Fargo to Grand Forks

November Profile

Ultimate B.O.D. at Waste Outfalls (L_o)	27000 lbs/day
Deoxygenation Rate Constant (k_r)	.35/day
Reaeration Rate Constant (k_2)	.75/day
Residual Upstream Deficit of D.O. (D_o)	1550 lbs/day
Respiration of Slimes (R_s)	
R.M.448 to R.M.441	900 lbs/day
R.M.441 to R.M.436	867 lbs/day
R.M.436 to R.M.428	783 lbs/day
Benthal Demand (B)	
R.M.448 to R.M.441	7500 lbs/day
R.M.441 to R.M.428	21600 lbs/day
Ultimate B.O.D. contributed from Sheyenne R.	2700 lbs/day
River Temperature	7.5°C.

November Profile without Sugar Plant Discharge

Ultimate B.O.D. at Waste Outfalls (L_o)	11200 lbs/day
Deoxygenation Rate Constant (k_r)	.06/day
Respiration of Slimes (R_s)	0
Benthal Demand (B)	
R.M.448 to R.M.441	2820 lbs/day
R.M.441 to R.M.436	2030 lbs/day

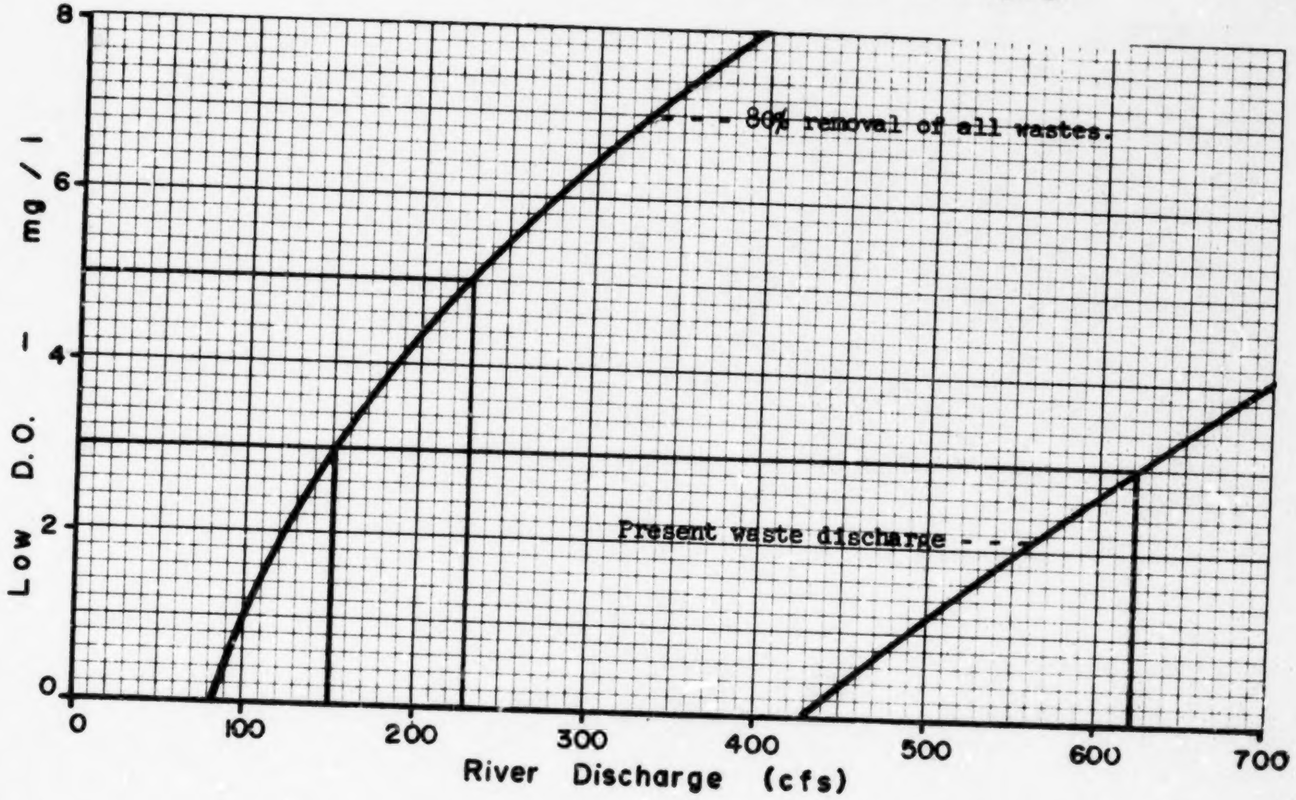
The sharp increase in D.O. results from the residual D.O. in the Sheyenne River. The D.O. remained below 5.0 mg/l for 16 miles in this stretch and would have remained below 5.0 mg/l for a greater distance except for the residual D.O. in the Sheyenne River.

The dashed curve represents a projection of the D.O. and B.O.D. values obtained in September at flows of 70 cfs to November at flows of 230 cfs, with appropriate transformation of the rate coefficients due to colder river temperatures. It is the best estimate of the probable D.O. sag curve through this critical stretch of river in November if the American Crystal Sugar Company plant at Moorhead had not been discharging its wastes. The values used in constructing this profile are also listed in Table A-4.

Chart A-4 illustrates the low D.O. that may be expected at any given river discharge for present waste loads and for 80 percent of waste removal at the most critical river temperature of 18°C. This is the highest river temperature at which all three waste sources may be discharging. These curves are based on the present discharges of 15,800 pounds per day of ultimate B.O.D. from the sugar beet plant and 7,700 pounds per day of ultimate B.O.D. from the combined effluents of the two municipal sewage treatment plants. The percentage removal is based on the total B.O.D. discharged, with no distinction between sources. The D.O. in the river will be severely depleted below the standard of 5.0 mg/l for continued discharge of the wastes with no abatement. To ensure 5.0 mg/l as a minimum D.O., stream flow exceeding 600 cfs would be necessary. This is far above any normal flow for this time of year (September) and is more than the regulating

Chart A-4
LOW D.O. vs RIVER DISCHARGE
RED RIVER OF THE NORTH
FARGO TO GRAND FORKS

River Temperature = 18°C.
All municipal and industrial wastes discharging.



facility at Orwell dam can reasonably supply. Even with 85 percent removal of all wastes, the stream flow required would exceed that normally expected. With total withholding of all sugar beet wastes, the minimum 5.0 mg/l of D.O. will not be achieved during the warm river temperature period for continued discharge of present municipal wastes at minimum river flows. Reduction of the present municipal treatment plant effluents must be accomplished when river discharge is below about 80 cfs in the warmer months and below 60 cfs in October and November. Chart A-5 indicates that at normally expected flows during the open water period of the beet processing campaign, no effluent can be tolerated from the sugar plant if the standard of 5.0 mg/l is maintained. Complete storage of all beet wastes during the entire campaign, for both open water and ice cover, with release in the spring runoff period, is necessary with present expected fall river flows. Furthermore, it can be shown from Table A-5 that for the mean expected spring runoff a further reduction of 10 percent in the B.O.D. must be accomplished so that all of the stored wastes may be released. During the once in ten year low monthly spring runoff, the present effluent load must be reduced a further 69 percent to maintain 5.0 mg/l in the river.

An alternative is low flow augmentation to permit the sugar plant to discharge the entire stored wastes without further treatment during the spring runoff. Inspection of Chart A-5 shows that for a guaranteed flow of 1000 cfs during the spring runoff, the entire stored wastes could be released by the middle of June. Since the once in

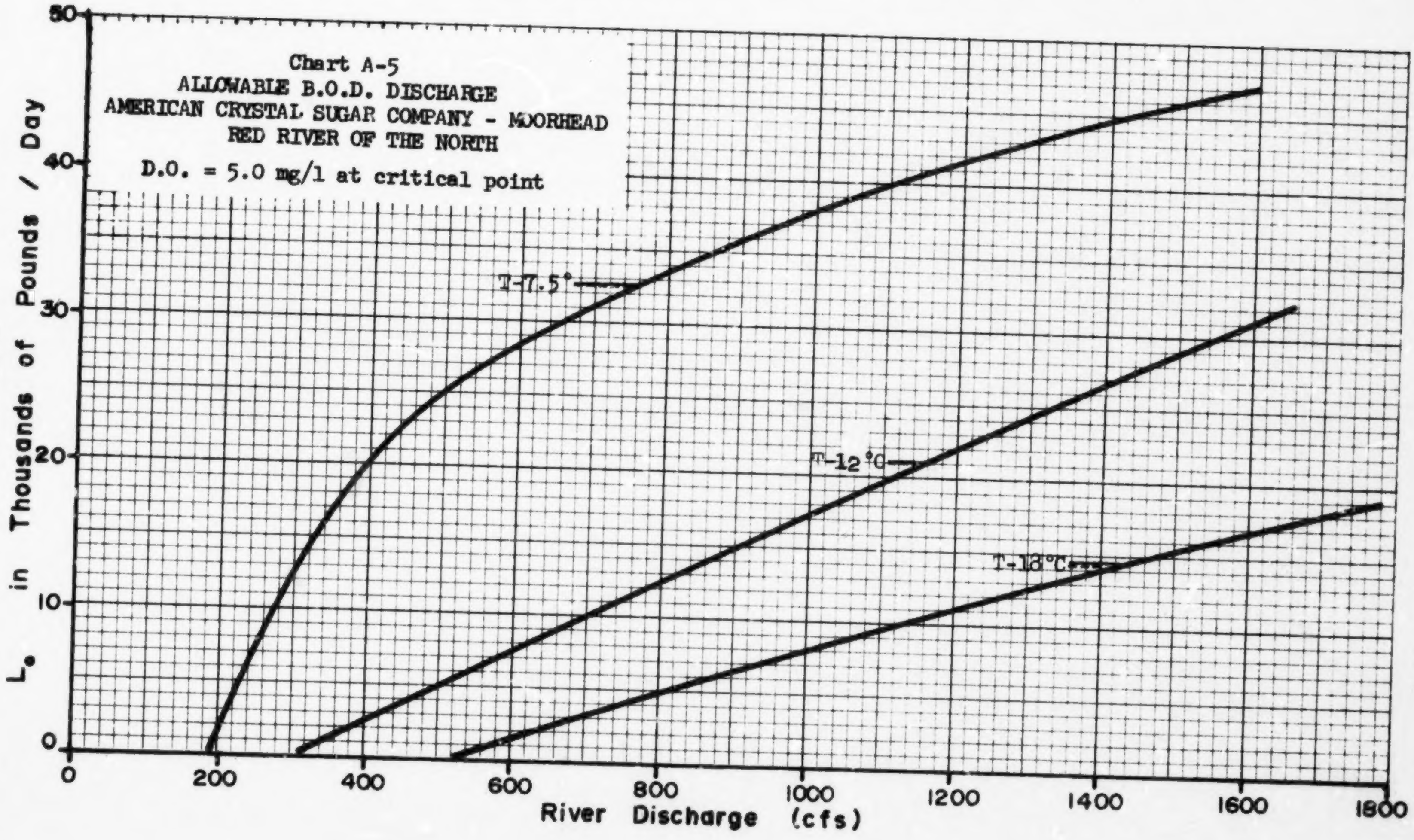


Chart A-5
ALLOWABLE B.O.D. DISCHARGE
AMERICAN CRYSTAL SUGAR COMPANY - MOORHEAD
RED RIVER OF THE NORTH

D.O. = 5.0 mg/1 at critical point

Table A-5

Schedule of Spring Release
American Crystal Sugar Co. - Moorhead

Average operating season = 150 days at 4,000 tons/day

B.O.D. effluent = 3.0 lbs/ton of beets

Total stored B.O.D. = 1,800,000 lbs.

Month	Mean Flow cfs.	Avg. River Temp. °C.	B.O.D. Release lbs/day	Total B.O.D. Release lbs/month
Mean Spring Runoff				
April	880	7.5	35,500	1,060,000
May	760	12.0	11,500	357,000
June	930	18.0	7,000	210,000

Total B.O.D. that can be released = 1,627,000 lbs.

Necessary reduction = $\frac{173,000}{1,800,000}$ = 10%

Once in Ten Year Low Spring Flow = 350 cfs.

April		7.5	17,000	510,000
May		12.0	1,500	46,500
June		18.0	0	0

Total B.O.D. that can be released = 556,500 lbs.

Necessary reduction = $\frac{1,243,500}{1,800,000}$ = 69%

ten year minimum monthly spring flow is 350 cfs, this represents 650 cfs of low flow augmentation. Table A-6 shows the required low flow augmentation for discharge in the fall with an 85 percent reduction of the present waste load from the sugar plant. Low flow augmentation for discharge in the fall would require a major increase in the present river flow amounting to more than 400 cfs in the mean year, even with 85 percent removal of the present effluent. Complete storage of beet sugar wastes during the fall campaign appears to be the only practical solution.

Based on the January phase of this survey, the effluents from the municipal treatment plants at Fargo and Moorhead are capable of causing complete deoxygenation of the river at the Grand Forks water intake during ice cover periods under certain conditions of river discharge. Chart A-6 shows zero D.O. will result at the Grand Forks water intake from municipal discharges at Fargo and Moorhead when the river discharge at Fargo is less than 170 cfs. The standard of 5.0 mg/l will be attained only when river discharge exceeds 210 cfs at Fargo. Chart A-7 illustrates the withholding of municipal wastes that will be necessary to maintain 5.0 mg/l of D.O. at the Grand Forks water intake. During January, the mean flow of the Red River at Fargo is 203 cfs. This flow is about the minimum at which the present municipal effluents may be discharged under ice cover to still maintain a standard of 5.0 mg/l at the Grand Forks water intake. At once in ten year minimum flow under ice cover (96 cfs), only 2800 lbs/day of ultimate B.O.D. or 11700 P.E. may be discharged by the municipal treatment

Table A-6

Low Flow Augmentation Required - Fall Runoff - 85% Removal
Discharge from American Crystal Sugar Co. - Moorhead

Month	Necessary Flow	Expected Flow	Augmentation
(1) Once in Ten Year Low Flow			
September	660	83	577
October	400	83	317
November	200	83	117
(2) Mean Year			
September	660	240	420
October	400	200	200
November	200	190	10

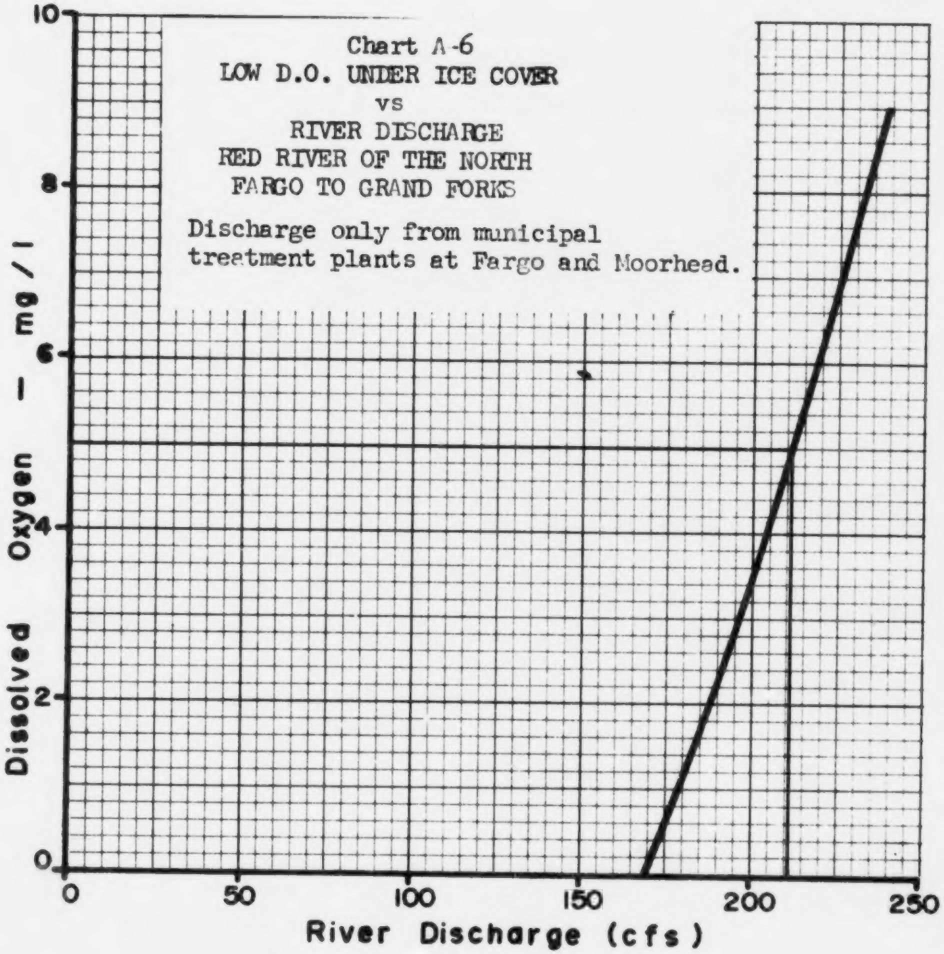


Chart A-6
LOW D.O. UNDER ICE COVER
vs
RIVER DISCHARGE
RED RIVER OF THE NORTH
FARGO TO GRAND FORKS

Discharge only from municipal treatment plants at Fargo and Moorhead.

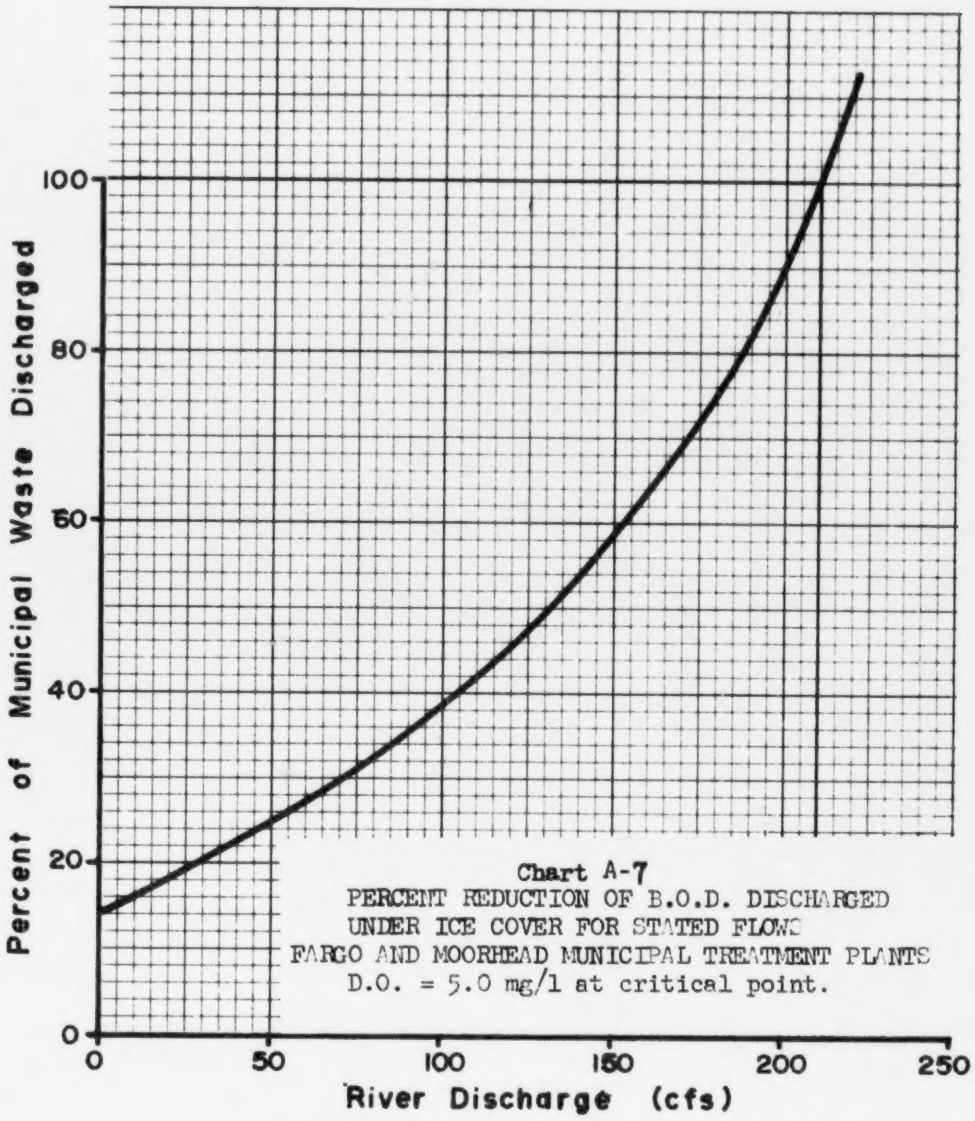


Chart A-7
PERCENT REDUCTION OF B.O.D. DISCHARGED
UNDER ICE COVER FOR STATED FLOWS
FARGO AND MOORHEAD MUNICIPAL TREATMENT PLANTS
D.O. = 5.0 mg/1 at critical point.

plants, a further reduction of 63 percent. To prevent recurring depletion of D.O. at Grand Forks, as experienced in the past under ice cover, provision must be made for reducing waste discharges during periods of lower than mean flow.

In September and November, the 5-day B.O.D. after reaching an apparent low at about R.M. 403 increased downstream although there was no significant source of waste in this reach. Also, the D.O. continued to increase and supersaturation occurred downstream from R.M. 357. These values of 5-day B.O.D. are listed in Table A-7. The 5-day 20°C. B.O.D. is not the total amount of oxygen demand exerted by the oxidizable matter available for decomposition but only that amount of it which is exerted in five days. As the reaction proceeds, a plateau is reached when the oxygen demand of the organic matter has been satisfied. This plateau is a measure of the total oxygen demand of the carbonaceous organic matter present. In a heterogeneous waste, there is both carbonaceous and nitrogenous organic matter. The carbonaceous material is more readily oxidizable and stabilization of this matter proceeds first. When most of the carbonaceous material has been satisfied, the biota necessary for the oxidation of nitrogenous material became predominant and the B.O.D. exhibits a sharp rise. This is known as the second stage demand. Table A-8 shows that, at R.M. 441, where was a substantial second stage demand in the river. It lists the substantial second stage demand of the Fargo sewage treatment plant effluent and the American Crystal Sugar plant wastes. The Moorhead sewage treatment plant would

Table A-7

5-day 20°C. B.O.D.

Red River of the North

Fargo to Grand Forks

Station	River Mile	5-DAY 20°C. B.O.D.			
		Sept.		Nov.	
		mg/l	lbs/day*	mg/l	lbs/day*
RR- 9	462	3.4	1285	2.0	2550
RR-10	441	9.8	3990	15.4	19170
RR-11	436	8.5	3500	10.7	13260
RR-12	426	7.6	6100	6.3	9900
RR-14	416	6.4	6260	4.2	7260
RR-15	403	5.9	5870	4.4	7610
RR-16	386	7.0	7100	4.8	8120
RR-18	375	7.0	8210	4.4	9110
RR-19	357	8.3	10050	4.4	9020
RR-20	347	6.7	8300	4.6	9500
RR-21	335	5.8	9320	4.7	10200
RR-22	319	4.5	7850	4.8	10350
RR-23	305	3.2	5750	5.4	11630
Tributaries					
SH-13	428-1	4.8	1750	3.4	1178
WM-17	380-3	1.8	275	1.1	405

* lbs/day = mg/l x Q (cfs) x 5.4

Table A-7 (Cont.)
5-Day 20°C. B.O.D.
Red River of the North
Fargo to Grand Forks

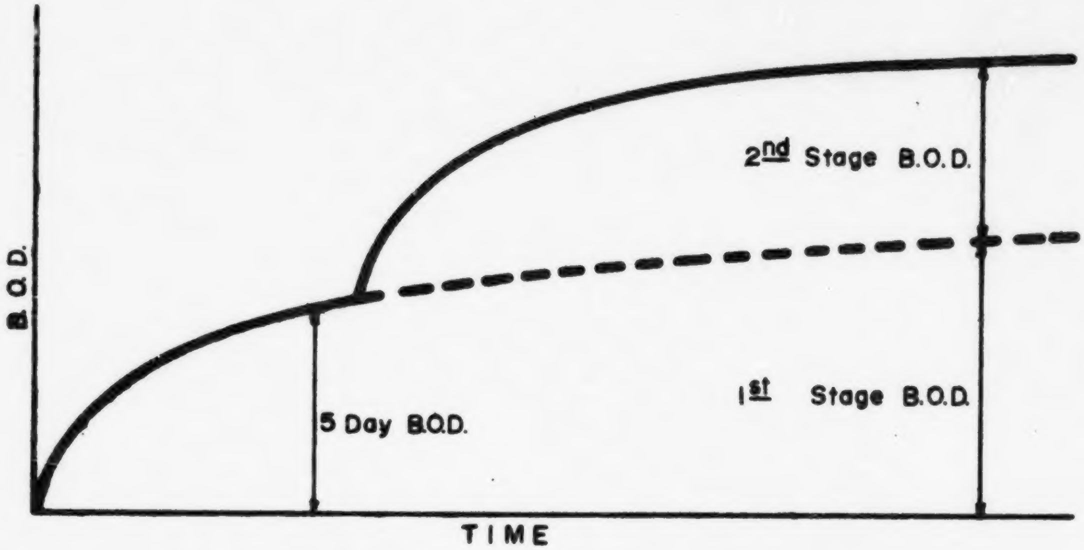
Station	River Mile	5-DAY 20°C. B.O.D.			
		January (1)		January (2)	
		mg/l	lbs/day	mg/l	lbs/day
RR- 9	462	1.8	1840	1.8	1840
RR-10	441	13.6	14200	5.8	6050
RR-11	436	8.0	8300	4.6	4750
RR-14	416	7.1	10150	2.4	3440
RR-15	403			2.2	3150
RR-16	386	4.9	6980	2.2	3130
RR-18	375	4.8	7550	2.2	3460
RR-19	357	8.0	12600	1.8	2850
RR-20	347	7.8	12500	2.1	3380
RR-21	335	7.0	11500	1.9	3110
RR-22	319	6.3	10300	2.4	3930
RR-23	305			1.5	2450
G.F.water intake				1.4	2290

(1) Mean of values resulting from ACS - Moorhead clean-up operation.

(2) Mean of values not affected by ACS - Moorhead clean-up operation.

Table A-8

First and Second Stage B.O.D. at Fargo-Moorhead



Location	1st stage Ultimate B.O.D.		2nd stage Ultimate B.O.D.		5-day B.O.D.	
	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day
R.M. 441*	19	23600	21.5	26750	17.1	21300
Effluent - American Crystal Sugar Co. Moorhead*	423	10600	207	5200	439**	11000
Effluent - Fargo Municipal Treatment Plant*	81	2710	107	3580	54	1800
Effluent - Moorhead Municipal Treatment Plant	229	3840	No data***		155	2590

* Results obtained from long term B.O.D. on grab sample.

** Second stage B.O.D. exertion had begun.

*** Moorhead treatment plant uses the same process as the Fargo plant.

also contribute a large second stage demand since it is the same type as at Fargo. This second stage B.O.D. began to exert its effect in the river downstream of R.M. 403, as was evidenced by the increase in B.O.D. during September and November. The oxidation of nitrogenous material produces nitrates. Nitrates in addition to phosphorus are a primary nutrient for the growth of algae which, in the presence of sunlight, convert carbon dioxide to oxygen. There was an increase in D.O. during the day to supersaturation. Oxygen production by algae during November is shown in Table A-9. In September, the time of travel in this reach was large due to the lower flows and considerably less second stage material was available. Oxidation of second stage nitrogenous material and the production of oxygen by algae occurred in the reach between R.M. 403 and R.M. 347. Downstream of R.M. 347, the D.O. dropped from 9.9 mg/l to 6.9 mg/l at R.M. 305. This was a result of a further additional demand on the oxygen resources caused by the decomposition of the suspended algae when the supply of nutrients had been depleted. The algae growth in the reach of river was caused by the discharge of wastes from domestic and industrial sources at Fargo and Moorhead. Because nutrients discharged in the sewage and industrial wastes from Fargo and Moorhead cause excessive algae growth downstream, the maximum practical reduction of the nitrogen and phosphorus in these wastes should be accomplished.

Table A-9

Photosynthesis Analysis*

Red River of the North

Fargo to Grand Forks - November 1964

Reach	River Miles	P #D.O./day	R #D.O./day	P + R #D.O./day
RR-10 to RR-11	441 to 436	- 311	- 556	- 867
RR-11 to RR-12	436 to 426	- 42	- 937	- 979
RR-12 to RR-14	426 to 416	+ 750	- 321	+ 429
RR-14 to RR-15	416 to 403	+ 1463	- 318	+1145
RR-15 to RR-16	403 to 386	+ 1946	- 545	+1401
RR-16 to RR-18	386 to 375	+ 1967	- 977	+ 990
RR-18 to RR-19	375 to 357	+ 5314	-3188	+2126
RR-19 to RR-20	357 to 347	+ 2282	-1140	+1140
RR-20 to RR-21	347 to 335	+ 2659	-1164	+1495
RR-21 to RR-23	335 to 305	+12506	-8754	+3752

* Obtained from light and dark bottles suspended in the river.

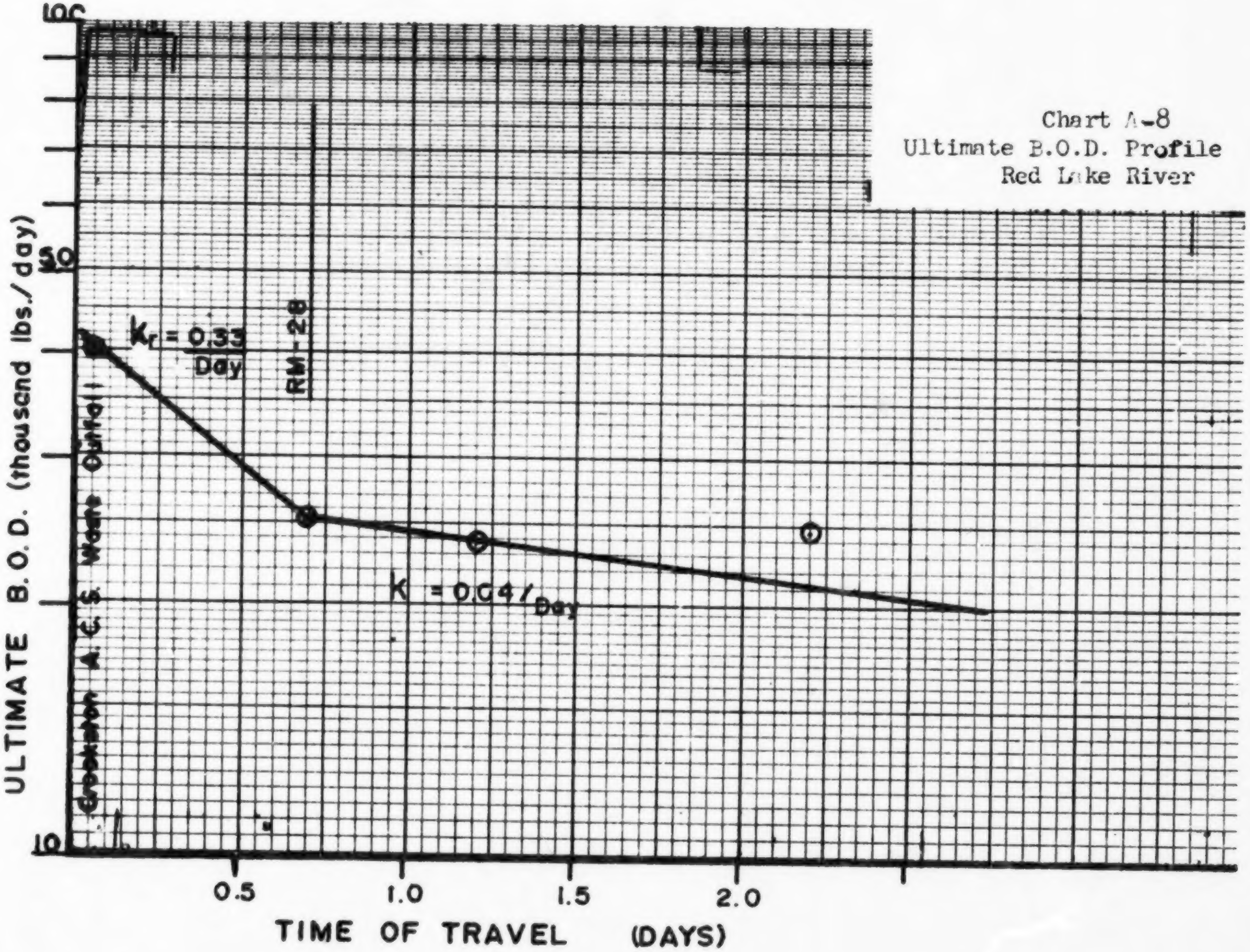
Red Lake River - Crookston to Grand Forks

No difficulty was encountered in this stretch because of bottom deposits but the growth of biological slimes was as pronounced below the Crookston American Crystal Sugar plant as below the Moorhead plant. The same rapid rate of deoxygenation was also observed during the time the sugar plant was discharging its wastes. Due to an excessively high river discharge and the absence of bottom deposits, the severe sag observed below Fargo-Moorhead did not occur below Crookston.

Chart A-8 shows the ultimate B.O.D. profile in the river versus time of travel. The rapid initial deoxygenation was a result of the satisfaction of the highly carbonaceous beet sugar waste. The abrupt change in the river deoxygenation rate occurred when the first stage B.O.D. of the sugar waste had been oxidized. Chart A-9 shows the calculated dissolved oxygen profile through this stretch and a comparison with the observed range of values. Table A-10 lists the values used in this calculation. For the conditions experienced in November, 1964, a minimum D.O. of 10.5 mg/l was obtained.

Projection to a discharge from the sugar beet plant during September when river temperatures can be expected to average about 18°C. resulted in Chart A-10. The ultimate B.O.D. of waste discharge from the beet sugar plant is about 21,000 lbs/day. Below 330 cfs of river discharge the minimum D.O. will be less than 5.0 mg/l with this waste load. At 112 cfs, which is the once in ten year monthly low flow for September, the minimum D.O. will approach zero. Storage or treatment of the present waste effluents will be required at river

Chart A-8
Ultimate B.O.D. Profile
Red Lake River



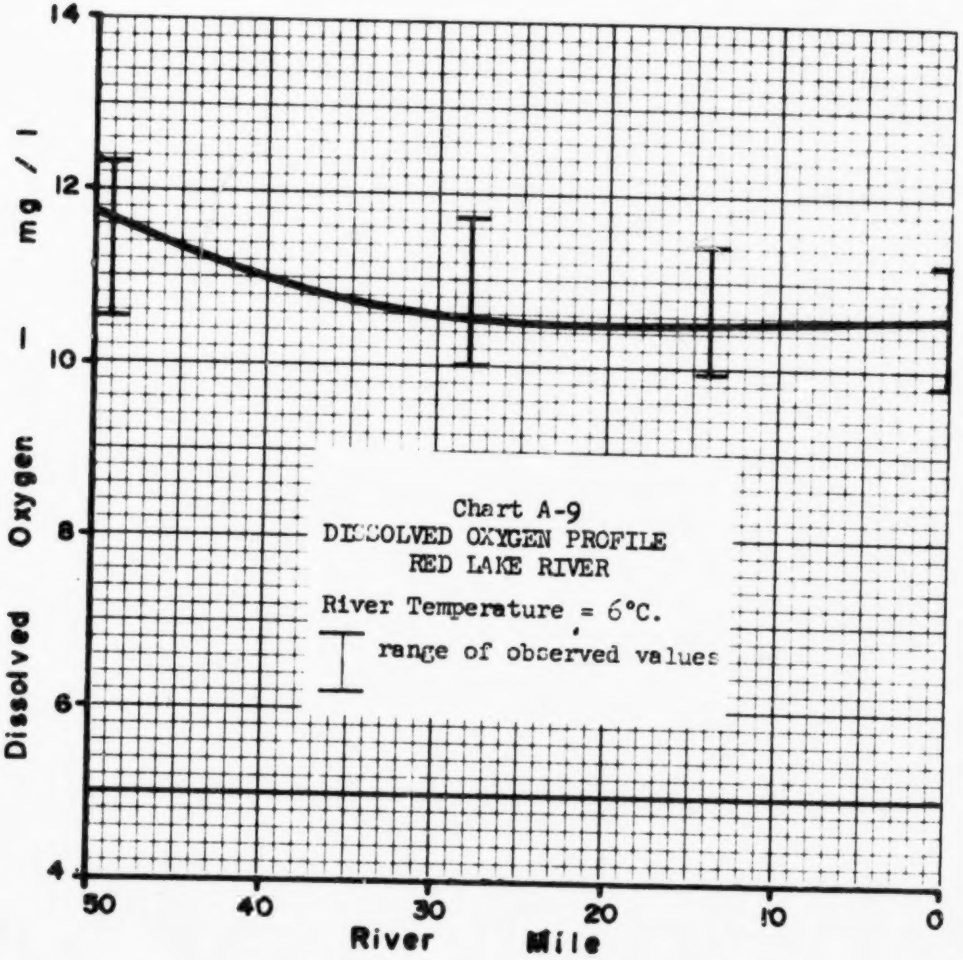


Chart A-9
DISSOLVED OXYGEN PROFILE
RED LAKE RIVER

River Temperature = 6°C.

range of observed values

Table A-10

Values Used in Calculation of D.O. Profile

Red Lake River - Crookston to Grand Forks

November Profile

Ultimate B.O.D. at Waste Outfalls (L_o)	42000 lbs/day
Deoxygenation Rate Constant (k_r)	
Crookston to Fisher	.33/day
Fisher to East Grand Forks	.04/day
Reaeration Rate Constant (k_2)	
Crookston to Fisher	.60/day
Fisher to East Grand Forks	.10/day
Residual Upstream Deficit of D.O. (D_o)	2650 lbs/day
River Temperature	6°C.

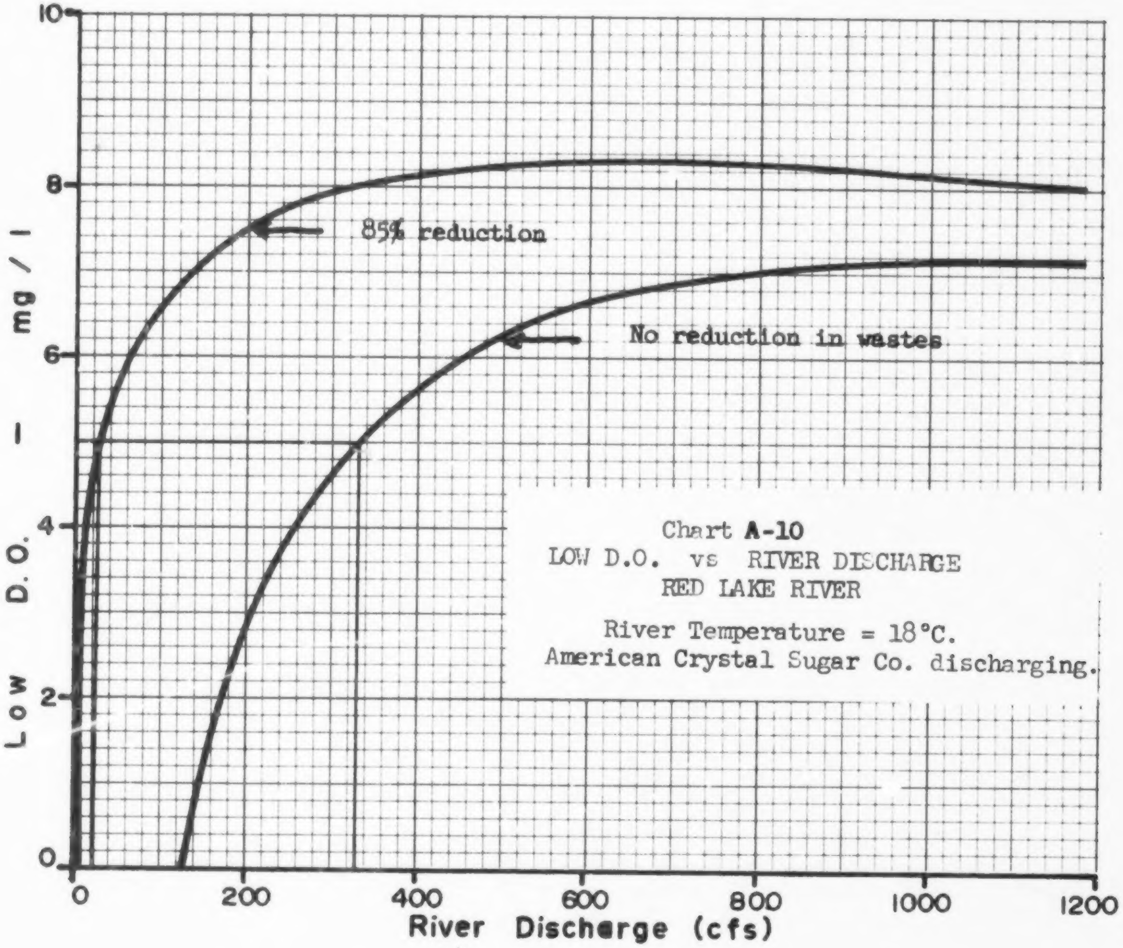


Chart **A-10**
LOW D.O. vs RIVER DISCHARGE
RED LAKE RIVER

River Temperature = 18°C.
American Crystal Sugar Co. discharging.

discharges less than 330 cfs to maintain 5 mg/l of D.O. in the river. This can be expected on the average about three times in eight years.

The amount of organic matter that may be discharged to the river to maintain a minimum D.O. of 5.0 mg/l under open water conditions is shown in Chart A-11. Some reduction in wastes will be required during the low flow years throughout the campaign period, as shown in Table A-11. Additional treatment or storage would be required during the fall campaign period about twice in five years. The flows expected in the river during the spring runoff are sufficiently high to permit discharge of the stored winter wastes in a short period after the ice breakup.

A consideration of low flow augmentation showed that supplementary stream discharges would not be necessary if there were a reduction in waste concentrations of 85 percent.

At East Grand Forks the Red Lake River had 24,500 pounds per day of ultimate B.O.D. still remaining from the waste discharge of the American Crystal Sugar Company plant at Crookston. This figure includes a substantial second stage B.O.D. which was exerted in the Red River of the North.

Red River of the North - Grand Forks to International Boundary

Below the Grand Forks metropolitan area, the dilution afforded by the confluence of the Red Lake and Red rivers mitigated the D.O. sag resulting from the waste discharges. Also, the B.O.D. of the effluent from the American Crystal Sugar plant at East Grand Forks,

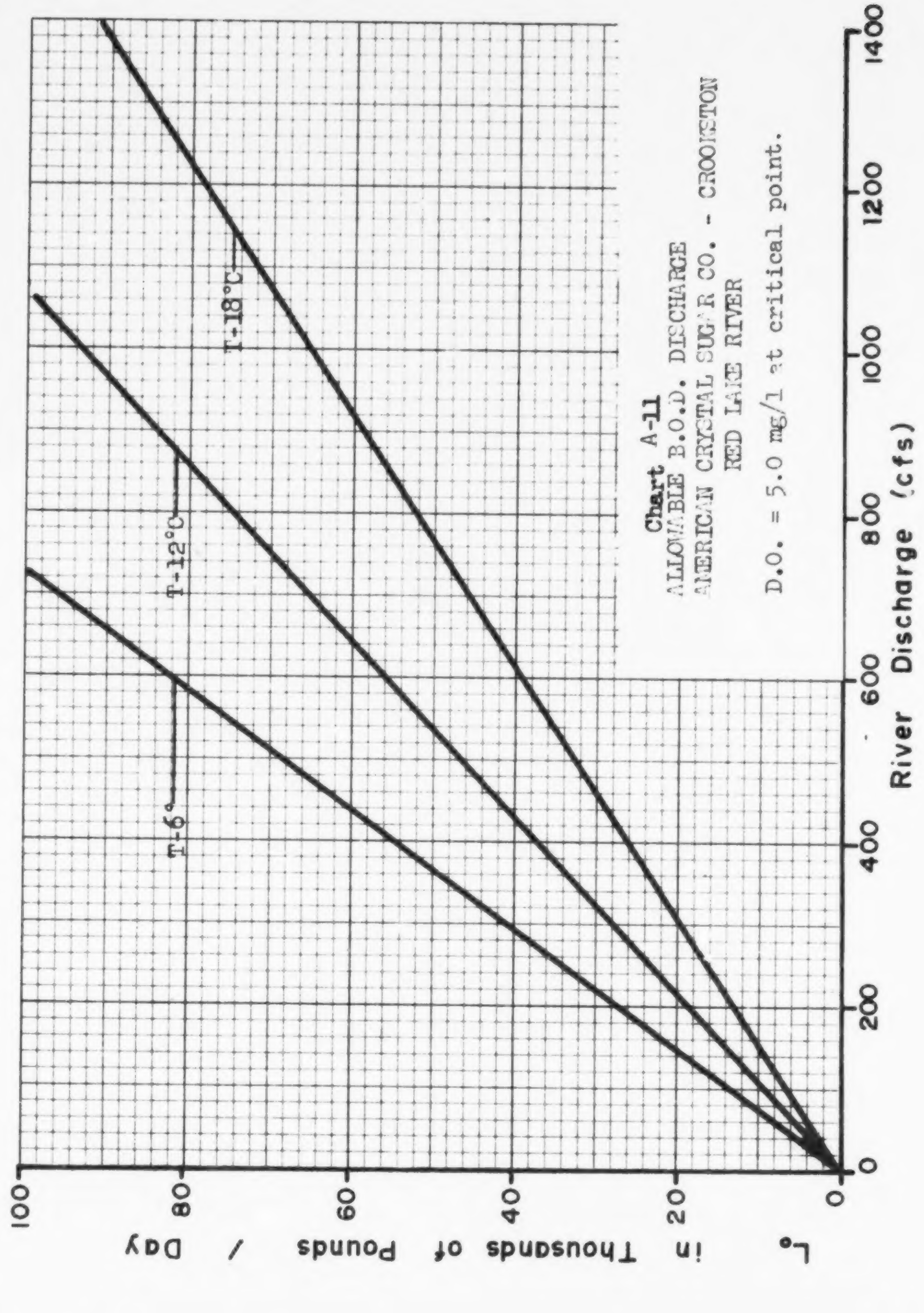


Chart A-11
ALLOWABLE B.O.D. DISCHARGE
AMERICAN CRYSTAL SUGAR CO. - CROOKSTON
RED LAKE RIVER

D.O. = 5.0 mg/1 at critical point.

Table A-11

Removal Required for Discharge in Low Flow Months

Discharge = 21,000 lbs/day

American Crystal Sugar Co. - Red Lake River

Month	Ten Year Monthly Low Flow	Ultimate B.O.D. Allowable Discharge lbs./day	Percent Removal
September	112	7,000	67 %
October	128	12,000	43 %
November	125	16,500	21 %

amounting to 9,000 lbs/day, was less than that of the other two plants and was combined in the river with the wastes from several potato processing operations and the residual pollution from the Red Lake River. This combination of significant amounts of potato wastes with the sugar waste lowered the rate of deoxygenation in the river so that use of the dissolved oxygen was slower. A small quantity of biological slimes was observed in the river below Grand Forks and these caused some acceleration in deoxygenation rate for a distance of about six miles below the sources of waste.

Chart A-12 shows the observed ultimate B.O.D. profile below the waste outfalls to R.M. 286. The remainder of the curve is the calculated profile of the first stage demand in the river obtained from the rate of first stage satisfaction at a sampling station immediately below the waste outfalls. This was necessary because the observed values were a reflection of both first and second stage demands proceeding at the same time. Table A-12 lists the observed B.O.D. in this stretch. The satisfaction of the demand produced a very slight D.O. sag in the river with a low value of 11 mg/l occurring 12 miles below the sources of wastes. The calculated values and the observed range of D.O. are shown in Chart A-13. The values used to construct this profile are listed in Table A-13.

Chart A-14 shows the effect of the wastes discharged at Grand Forks-East Grand Forks on D.O. for various conditions of river discharge at a river temperature of 18°C. For continued waste discharge, reduction in the present load would be required only for river discharges

Chart A- 12
Ultimate B.O.D. Profile
Grand Forks-East Grand Forks to Oslo, Minn.

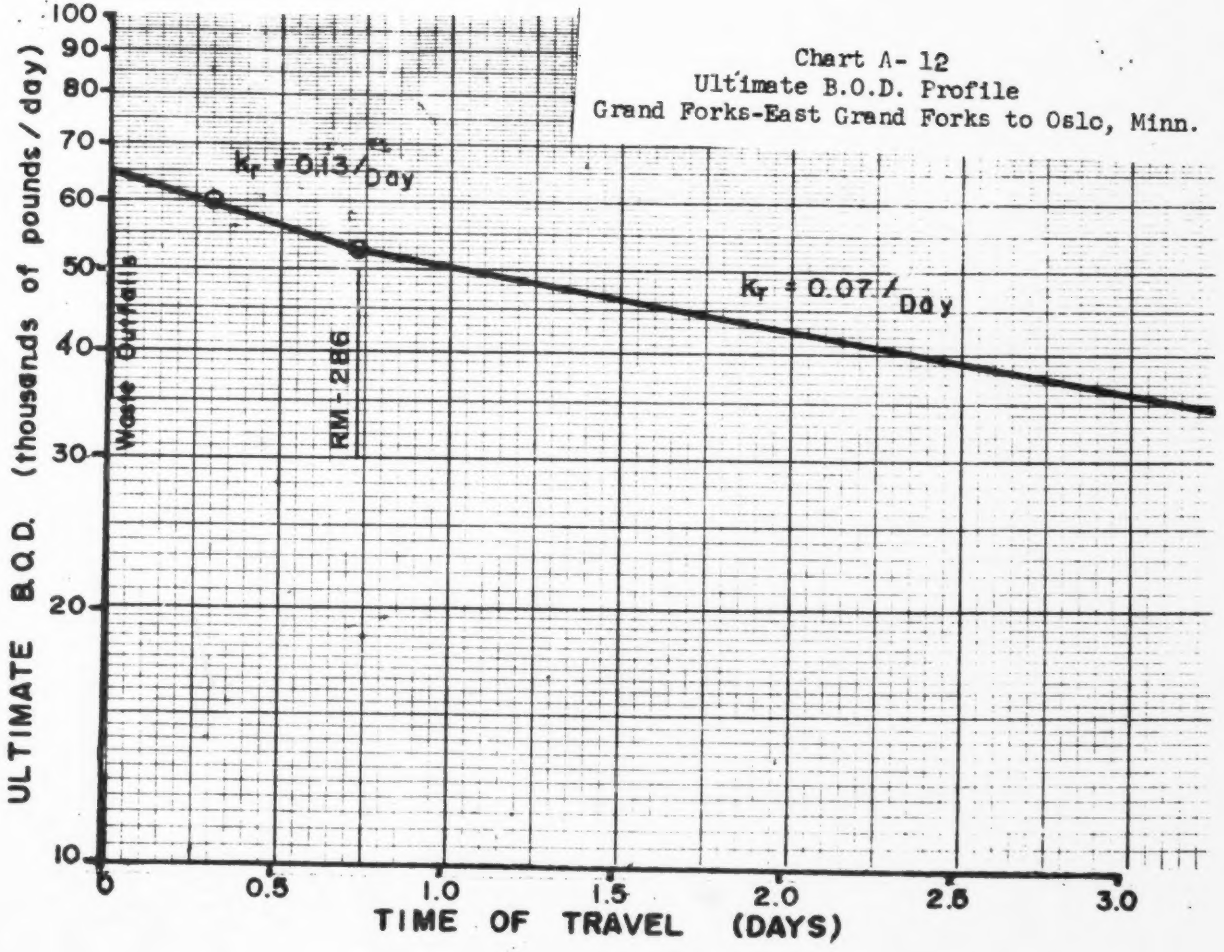


Table A-12

5-Day 20°C. B.O.D.

Red River of the North

Grand Forks to International Boundary

Station	River Mile	5-DAY 20°C. B.O.D. September mg/l	September lbs/day*	November mg/l	November lbs/day*	January mg/l	January lbs/day*
RR-27	298	2.3	7600	3.4	28090	2.2	11350
RR-28	292	3.6	12100	6.0	49090		
RR-29	286	3.2	11250	5.2	43070		
RR-30	279	3.0	10800	4.8	39500	1.7	8700
RR-31	274	2.5	9500	4.6	38290	1.8	9150
RR-32	254	2.6	10000	4.9	41220		
RR-34	236	2.1	8500	4.4	37460	1.7	8550
RR-36	208	1.9	7950	4.2	36620	1.2	6000
RR-37	176	2.0	8550	3.7	31210		
RR-39	158	1.7	7800	3.5	28720	1.3	6400
Tributaries							
FR-33	243-7	11.2	360	9.1	540		
PR-35	222-5	20.2	870	6.0	240		
PE-38	158-0.5	1.6	1000	1.8	495		

* lbs/day = mg/l x Q (cfs) x 5.4

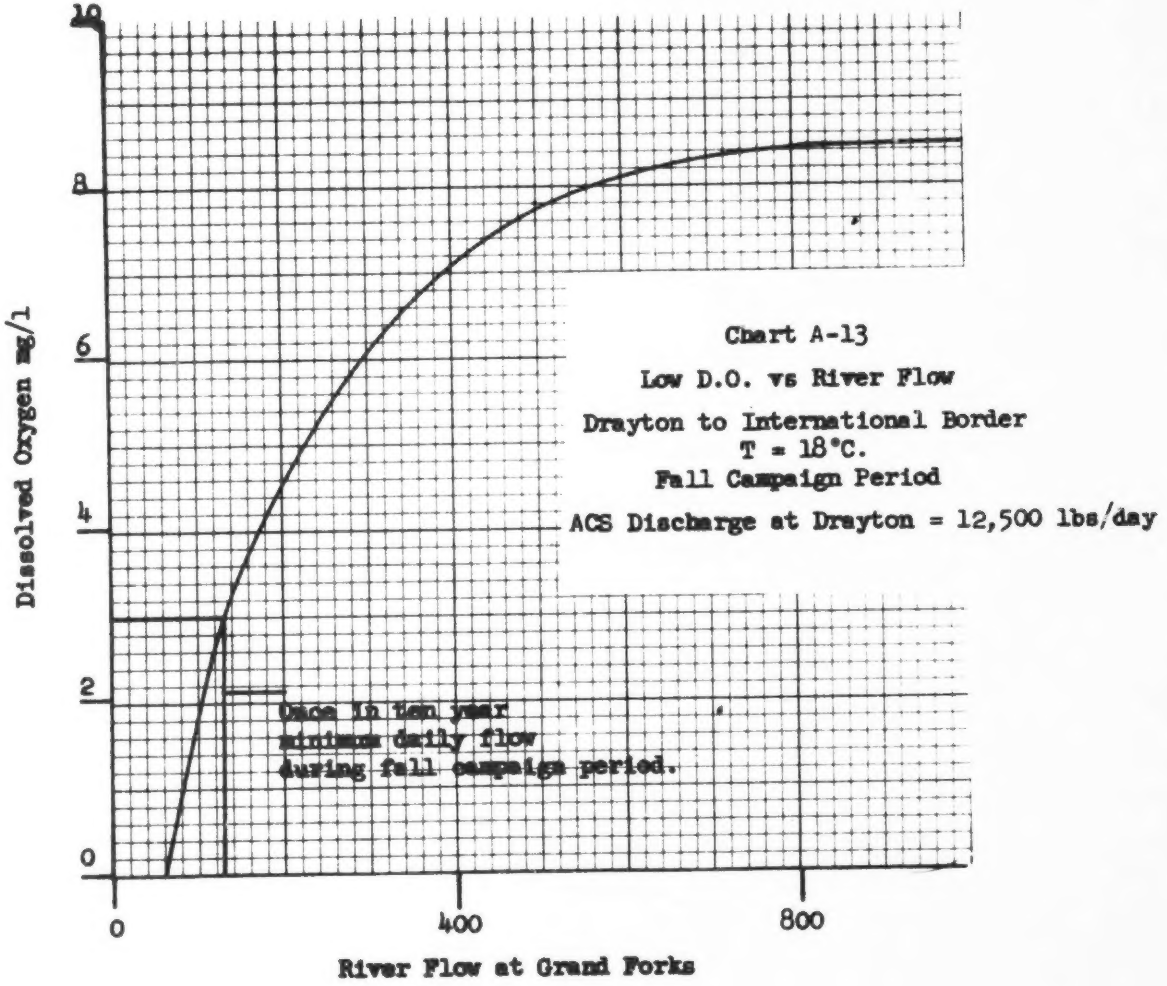


Chart A-13

Low D.O. vs River Flow

Drayton to International Border
T = 18°C.
Fall Campaign Period

ACS Discharge at Drayton = 12,500 lbs/day

Table A-13

Values Used in Calculation of D.O. Profiles

Red River of the North - Grand Forks to International Boundary

November Profile

Ultimate B.O.D. at Waste Outfalls (L_o)	65000 lbs/day
Deoxygenation Rate Constant (k_r)	
R.M. 296 to R.M. 286	.15/day
R.M. 286 to R.M. 274	.07/day
Reaeration Rate Constant (k_2)	.35/day
Residual Upstream Deficit of D.O. (D_o)	1900 lbs/day
River Temperature	6°C.

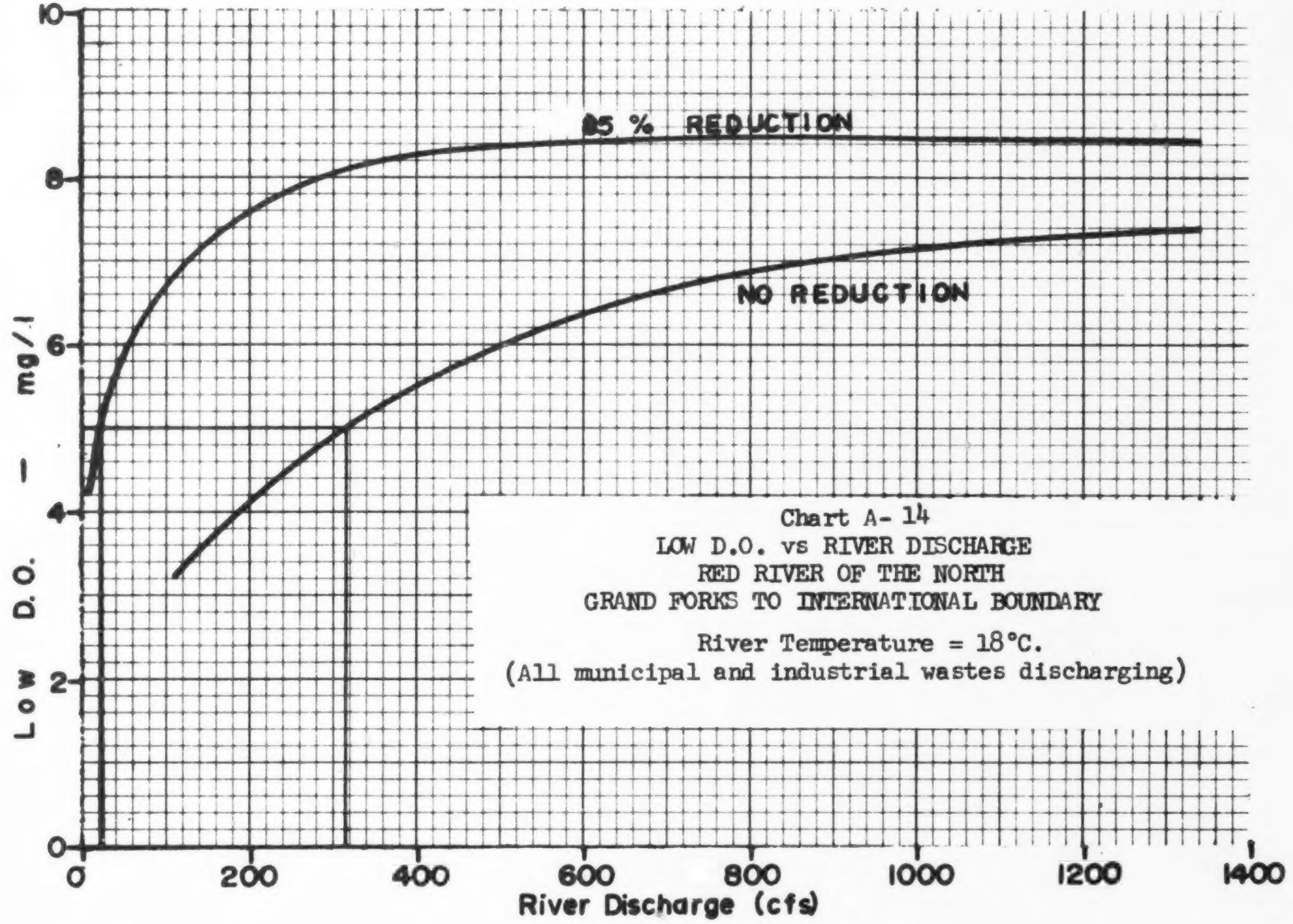


Chart A- 14
LOW D.O. vs RIVER DISCHARGE
RED RIVER OF THE NORTH
GRAND FORKS TO INTERNATIONAL BOUNDARY

River Temperature = 18°C.
(All municipal and industrial wastes discharging)

less than 300 cfs during open water periods to maintain a standard of 5.0 mg/l. Since the once in ten year low flow during the beet sugar campaign is greater than 300 cfs, no storage of beet wastes would be required during the fall period of the campaign to maintain D.O. levels if the potato wastes are removed and treated in the Grand Forks municipal system. This conclusion is reinforced by Chart A-15 which shows that even with warm river temperature (18°C.), all of the present quantity of wastes may be discharged.

The river recovers from the pollution discharged in the Grand Forks area before reaching the location of the proposed American Crystal Sugar plant at Drayton. The river also will recover from the discharge of the Drayton sugar plant before the International Boundary is reached. A D.O. of 5.0 mg/l can be maintained for an assumed discharge of 24000 pounds from the plant at river flows greater than 420 cfs and 18°C. river temperature. The assumed discharge is based on 4.0 pounds per day of B.O.D. per ton of beets processed. Since the once in ten year low flow during the beet sugar campaign is greater than 420 cfs, the flow below which storage or treatment must be provided, it is anticipated that no storage will be required during the fall period of the campaign to maintain adequate D.O. levels below Drayton. However, if slime growths develop and accelerate the rate of deoxygenation and if the discharge creates a significant benthal demand and destroys bottom organisms, detention will be required. Complete withholding during the period of ice cover will be necessary.

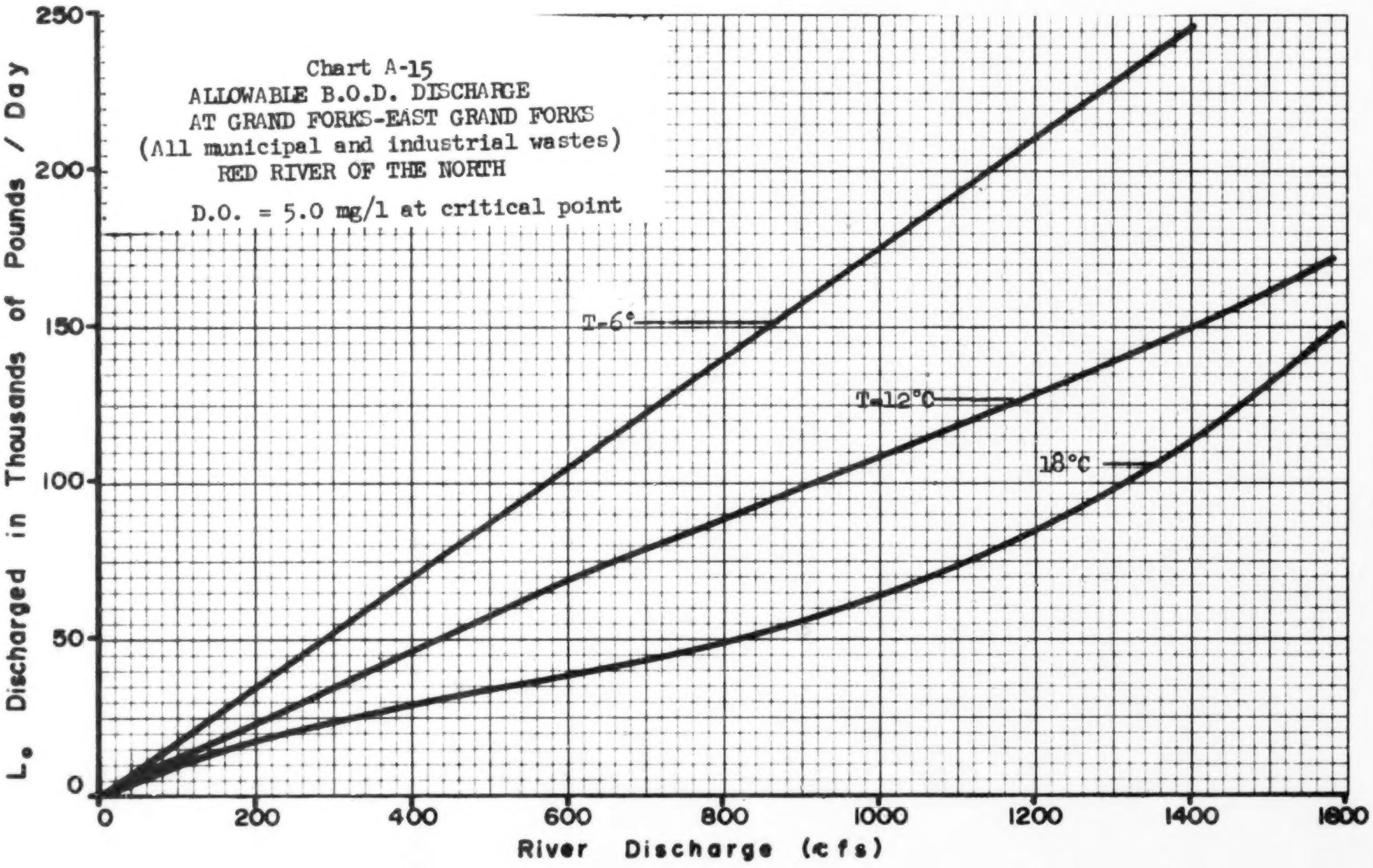


Chart A-15
ALLOWABLE B.O.D. DISCHARGE
AT GRAND FORKS-EAST GRAND FORKS
(All municipal and industrial wastes)
RED RIVER OF THE NORTH

D.O. = 5.0 mg/l at critical point